CLEARING THE DATA SMOG: SURVIVING INFO GLUT

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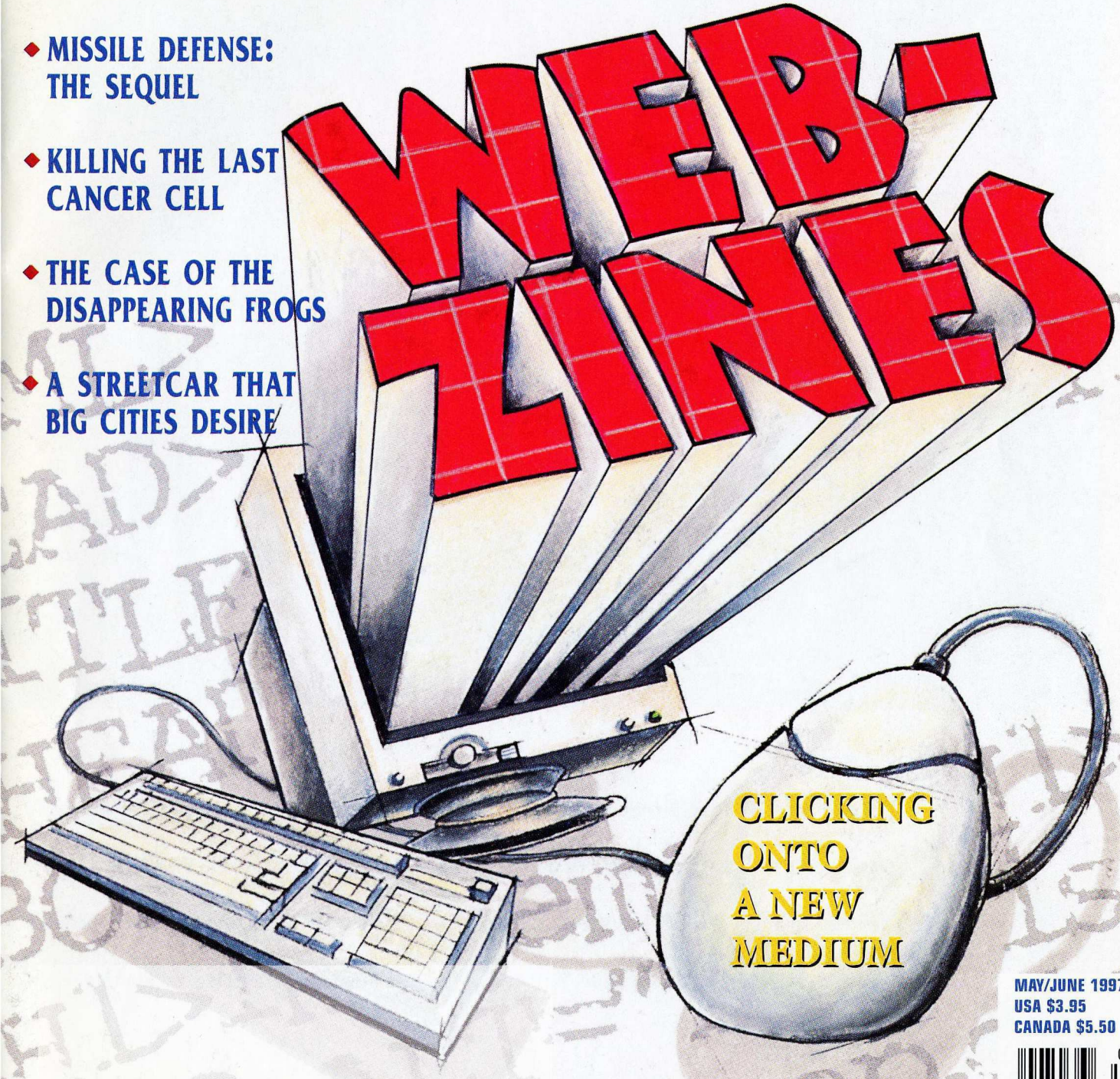
TECHNOLOGY REVIEW

- MISSILE DEFENSE: THE SEQUEL
- KILLING THE LAST CANCER CELL
- THE CASE OF THE DISAPPEARING FROGS
- A STREETCAR THAT BIG CITIES DESIRE

WEB-ZINES



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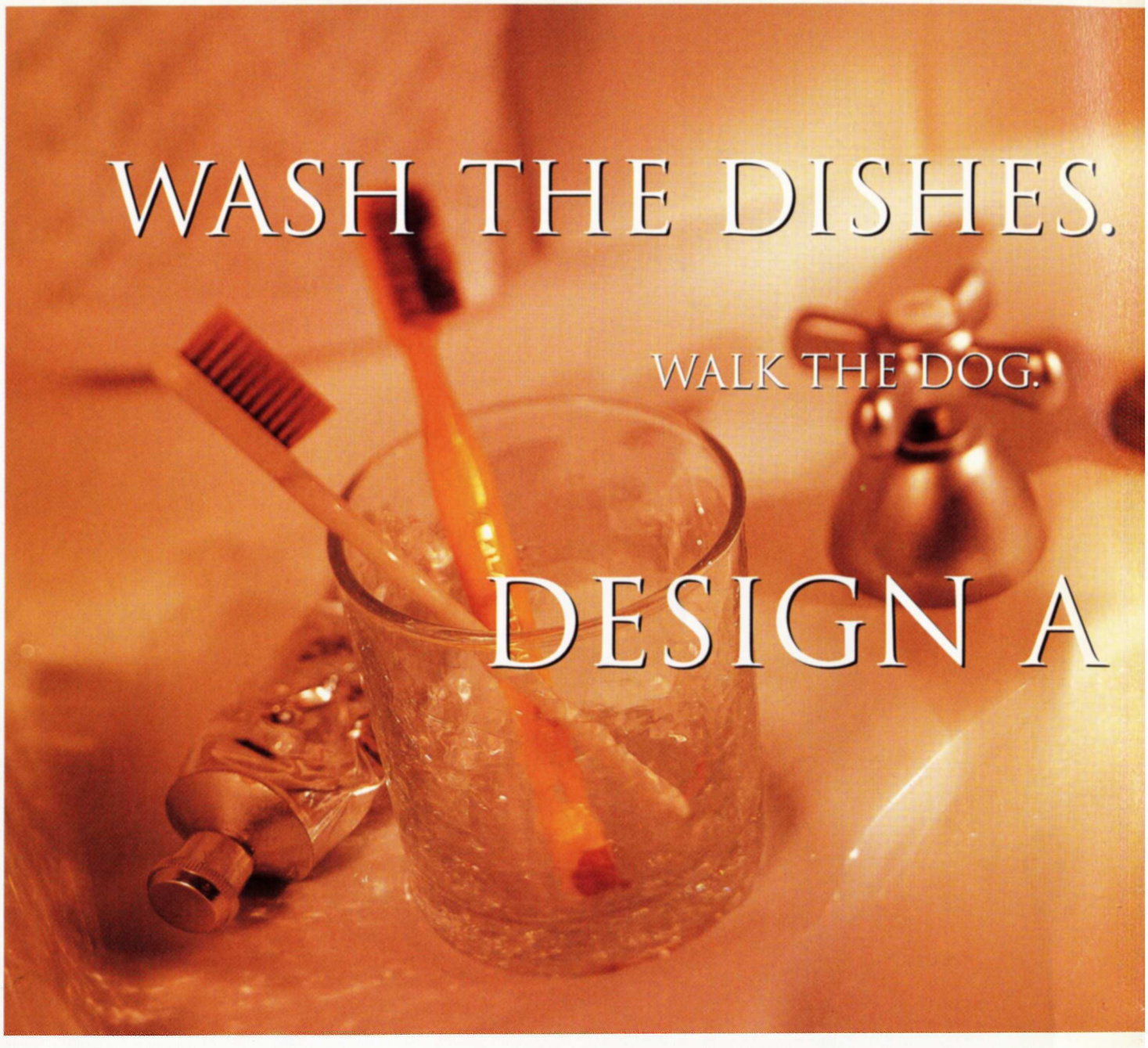

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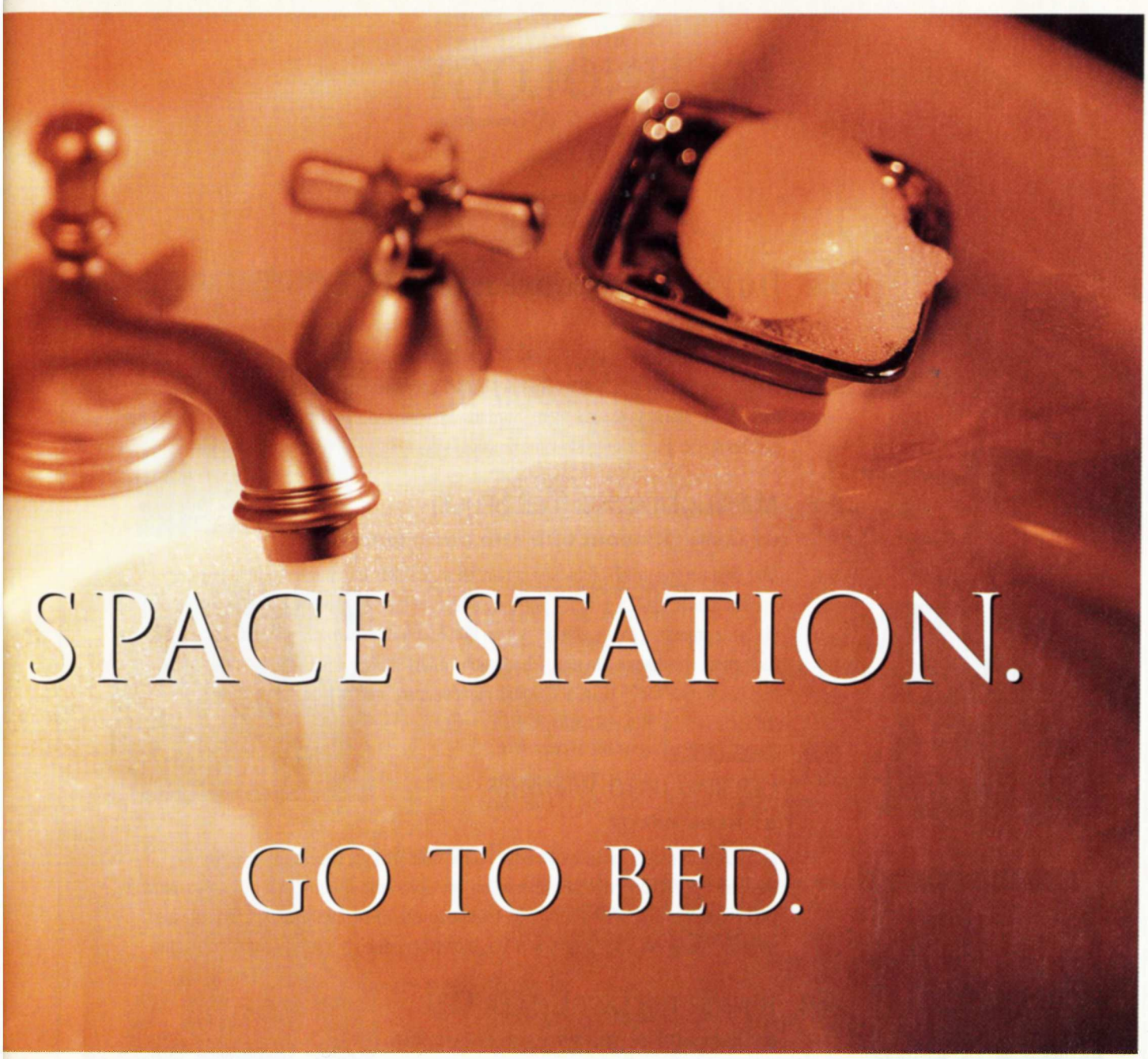

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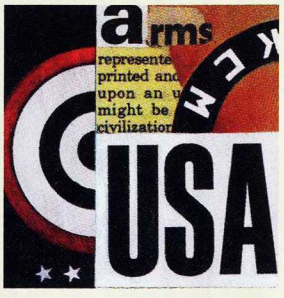
18 Data Smog: Surviving the Info Glut

BY DAVID SHENK

Feeling dazed? Stressed? Even burnt-out by today's veritable flood of bytes? That's the dark side of the Information Age. As the computer capacity to churn out ever greater volumes of data exceeds our ability to process them, humans are often falling victim. In an excerpt from his new book, the author suggests some practical ways to head off the personal and social chaos.



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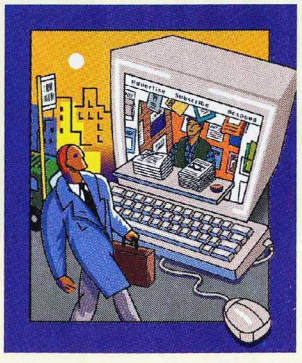
BY LISBETH GRONLUND AND DAVID WRIGHT

After abandoning much of the Reagan-era effort to shield the country from long-range nuclear attack, the U.S. is again pursuing a high-tech system of national defense as well as plans for protecting troops abroad. But no hostile countries actually have the missiles most such efforts are designed to stop. What's more, many of these costly efforts would violate a treaty that has worked for 25 years and would, paradoxically, prevent further cuts in nuclear weapons.



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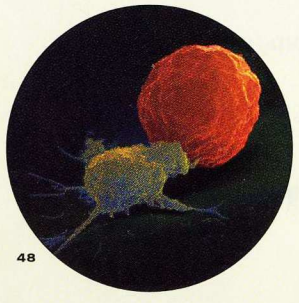
38 COVER STORY

Clicking onto Webzines

BY HERB BRODY

Magazines that exist exclusively on the World Wide Web are taking advantage of the medium by providing vigorous interaction, on topics both sublime and ridiculous, among writers and readers. While continuing to experiment, these online publications are also trying to figure out how to survive in a milieu where nobody wants to pay for anything.



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48 Killing the Last Cancer Cell

BY RONALD M. KLINE AND SUNIL CHADA

Chemotherapy, even when effective, may leave a few cancer remnants—resistant strains that spawn an even more virulent version of the disease. Research into the immune system's elegant methods of attacking invaders suggests techniques to eliminate lingering malignancy.

56 The Case of the Vanishing Frogs

BY TIMOTHY R. HALLIDAY AND W. RONALD HEYER

Why is *Rana muscosa*, a yellow-speckled mountain frog, disappearing from pristine streams and ponds in California's Sierra Nevada range? When scientists set out to solve the mystery, they discovered similar steep declines in frog populations throughout the world. Are these amphibians, like canaries in a coal mine, providing early warning of general environmental peril?

COVER ILLUSTRATION BY JON MCINTOSH

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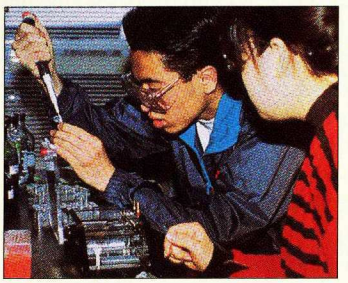

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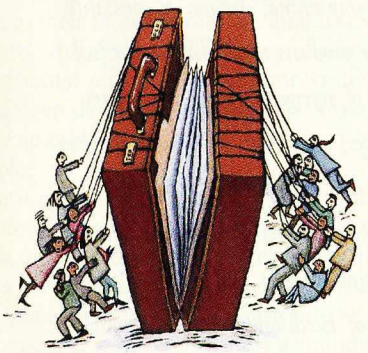

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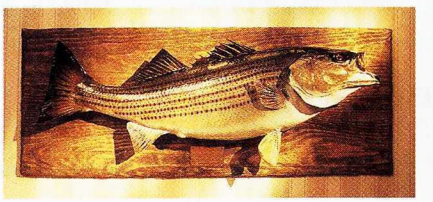

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First Line

GOOD-BYE, DOLLY, . . .

. . . unless the government permits, oversees, and funds sensible cloning research.

LATE in May, the National Bioethics Advisory Commission, an 18-member panel of experts in medicine, law, and ethics, is scheduled to give President Bill Clinton some novel science advice. It will recommend possible federal actions to prevent abuse of science's newfound ability to clone adult mammals—that is, to produce exact genetic copies of an existing animal from a single body cell.

The cause of this unprecedented fast-track activity is, of course, a sweet-faced Scottish sheep named Dolly. We can debate whether Dolly is, as one columnist would have it, the biggest story of the century. But persuading DNA from a specialized adult cell to return to its youthful undifferentiated state and initiate a brand-new life is surely a milestone in biology, and offers a lesson in why seasoned observers of science never say "never."

We can already glimpse a few of the practical applications of cloning, such as duplicating especially productive livestock and saving vanishing species. But if the clones can be genetically engineered—the next goal of Dolly's developers at the Roslin Institute near Edinburgh—the possibilities expand to include medicine: herds of identical animals that function as living drug factories, producing medically valuable proteins in their blood or milk; animal models for studying human diseases and testing treatments; pigs whose immune systems have been designed to make their organs more suitable for transplantation into sick people.

As is the case with any trailblazing scientific development, cloning's most important consequences doubtless lie hidden in the mists of the future, although we can assume that some of them will likely astound us. A lot of people fear that the most astounding will be a world of Frankenstein's monsters: clones of human beings. There are many technical hurdles between here and there, but the experts are pretty sure that what can be done with sheep can eventually also be done with *Homo sapiens*.

Few people have been able to think of good reasons for cloning humans, but everybody seems to be able to imagine the nightmares. Consider, for example, a world without sex because cloning does away with fathers. Or endless duplicates of individuals—Nobel laureates, movie stars, criminal masterminds, fascist dictators, whoever—created with or without their knowledge. Or how about raising the dead, literally, from the cells of corpses?

It's no wonder that Dolly is causing some of us to come unglued. President Clinton dealt quickly with this ostensible national emergency and immediately declared a moratorium on human cloning. This stops nothing, since as far as we know, no such research is actually going on. To be fair, the president was reportedly trying to head off some much more panicky legislation. Still, the proposals began tumbling in anyway. A Michigan congressman, for example, would permanently ban human cloning; violators would be fined $5,000. A New York legislator thought such punishment a wrist-slap; he wanted to send human cloners to prison for 7 years. "We're dealing with something of great concern to humanity," he said. "We ought not to permit a cottage industry in the God business."

But it is precisely out of concern for humanity, and to prevent a rush *into* the God business, that we should resist the urge to ban, much less to criminalize, such research. We should learn from our mistakes. Recall that when test-tube babies burst into the world in the 1970s they provoked much the same consternation as Dolly. I was among those who urged the government to stay out of this field. Many voiced moral or religious objections to research with early human embryos. I did not, but I thought then (and still think) that solving people's fertility problems should not be high on the wish list of the National Institutes of Health. The naysayers won the argument—so thoroughly, in fact, that using government money for research with human embryos remains forbidden in the United States to this day.

I regret this profoundly. In addition to its retarding effect on some useful research, forcing test-tube baby work into private labs has meant that the fertility industry, essentially unregulated, has pretty much run its own show. Or perhaps I should say, circus: In California, eggs and embryos stolen from scores of women were distributed to researchers and implanted in other women. In Britain, thousands of frozen embryos were destroyed because their parents failed to claim them, despite the Vatican's exhortations that the embryos be "adopted"—brought to term by 6,000 volunteer moms. Around the world, some fertility centers have claimed fictitious rates of pregnancy success. Such claims not only attract customers but keep them trying over and over—at a cost of some $10,000 each time. Yes, many thousands of test-tube babies have been born, but for every successful couple, four others are sent away in despair.

The surest way to guarantee that cloning—whether of animal or human cells—will be misused is to forbid it or restrict it to private labs, which will drive it out of the light of day. The simplest way to forestall such an outcome is for us citizens to underwrite some cloning research (although, to foster rational discourse, probably not on human cells, at least not at first). As today's biology goes, that research would not be terribly costly, and there are reasonable scientific and practical arguments for doing it—exploring its potential in feeding people and curing their ills and in other useful applications that we cannot yet foresee. It would give us grounds for formal oversight if that became desirable. And thanks to scientific exchanges at meetings and over the Internet, not to mention scientific gossip, we would improve our chances of learning what's going on in private labs as well as government-funded ones. ■

—TABITHA M. POWLEDGE

TABITHA M. POWLEDGE, a science journalist specializing in genetics and neuroscience, is the author of Your Brain: How You Got It and How It Works *(Scribners, 1995).*

Letters

AUTO BODIES LIGHTEN UP

"A Practical Road to Lightweight Cars" (*TR January 1997*) by Frank R. Field III and Joel P. Clark was distressing because it erroneously conveyed both basic and technical facts about the Partnership for a New Generation of Vehicles (PNGV). First, the authors misidentify PNGV as the Program for a New Generation of Vehicles. "Partnership" is an important distinction because this effort to develop environmentally friendly family sedans that triple the fuel efficiency of today's similarly sized cars is a cost-shared one between the U.S. auto industry and the federal government. Second, the partnership was announced by President Clinton on September 29, 1993, not 1994 as the article claims. Third, PNGV was not "inspired" by Amory Lovins, as the table of contents claims. Rather, it is a high-priority Clinton administration initiative.

The authors assert that "the key to improving a vehicle's fuel economy is weight reduction." While weight reduction is extremely important, it is not the only factor in creating a fuel-efficient car. In the earliest stage of the PNGV, we identified 14 technologies where significant improvements would ameliorate the greatest energy losses, in areas such as energy conversion (engines), energy storage (batteries), materials, and enabling technologies. We do not have the luxury of concentrating on any single area; advances in several are necessary. To meet the goals of the partnership within its time frame—a decade from its announcement—we must draw on technologies that promise a significant increase in performance, not an incremental one.

Several specific points in the article also deserve comment:

Crashworthiness. Field and Clark claim "a lightweight car cannot rely on its structural components to protect passengers in the event of a crash and so will need to employ additional systems, like airbags, which add some weight." On the contrary, lightweight materials can be configured to make a car as safe as today's vehicles. Innovative design concepts can capitalize on advanced materials that absorb and disperse crash energy, a strategy certainly more effective than air-bags.

Conveniences. We contest the authors' argument that dramatic improvements in fuel economy will result in "less room and fewer conveniences" than the American consumer typically expects. If the authors are referring mainly to gas-guzzling sport-utility vehicles, then we agree with them.

Price of carbon fiber. The authors doubt that carbon fiber prices will fall from $20 to $5 per pound because "the production of carbon fibers is not necessarily amenable to economies of scale." Carbon fibers are now available at $8 per pound. Fiber-processing improvements and economies of scale, which are predicted by all fiber manufacturers, are expected to lower the price even further.

The authors conclude that "a supercar like that envisioned by the Partnership for a New Generation of Vehicles . . . is beyond our capabilities today and for the near future." They describe efforts to achieve a supercar as a "technological chimera." This unflattering judgment of the PNGV, which is only four years into

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its 10-year program, is undeserving and not scientifically correct. We are only now concluding the first phase of the partnership, yet we have made considerable progress: technologies have been surveyed and evaluated, and research redirected in some cases. And, contrary to the authors' assertion, we have not yet chosen or excluded *any* technology. Later this year, we plan to select the most promising technologies for incorporation into drivable experimental and concept vehicles. Readers can learn more about our progress from "PNGV Technical Accomplishments," a 1996 report that is available from the PNGV secretariat.

ROBERT M. CHAPMAN
Chair
PNGV Government Technical Task Force
U.S. Department of Commerce
Washington, D.C.

Field and Clark claim that advanced-polymer-composite auto bodies are a costly, impractical, and risky leapfrog to untried or unavailable manufacturing processes and unattractive cars. We have documented exactly the opposite in analyses for many leading professional conferences on composites and cars. Field and Clark cite our papers, offer no supporting analysis of their own, yet dismiss or ignore our evidence that:

- Auto bodies that are at least as stiff and strong as their steel counterparts and two- to threefold lighter can cost no more than modestly lighter auto bodies, partly by economizing on costly materials.
- With ten- to fiftyfold fewer parts, not threefold as the authors claim, these auto bodies are simpler to manufacture and assemble.
- They can use two- to tenfold cheaper tooling and equipment.
- Ultralight bodies can also make the rest of the car, which accounts for 80–90 percent of its total cost, cheaper by downsizing or eliminating other parts (for example, the GM Ultralite noted in the article doesn't need power steering or power brakes) and enabling mechanically simpler hybrid-electric drive systems.
- The problems of affordably mass-producing composites—historically due to using inferior types or designs, or mixing composites with steel—can be solved by synergistically integrating new processes already demonstrated separately in volume production, as Sotira has shown by producing Class-A-finish, glass-reinforced car components at the rate of more than 1,000 a day.
- Advanced-composite bodies can offer distinctive performance, safety, and amenity *advantages*. For example, decoupling mass from size improves acceleration and roominess, while crash-energy absorption per kilogram increases fivefold. Hence, many automakers are considering adding composite crash structures to steel cars.

Our 1995 paper for the International Body Engineering Conference (www.rmi.org/hypercars/) used the industry-standard model to estimate the cost of the GM Ultralite's carbon-fiber body at $2,500–$3,100, excluding later savings in finishing, other components, and car assembly. Field and Clark's single estimate of $6,400 for the same body assumed that carbon fiber cost 2.5 times its actual 1995 bulk price and manufacturing/assembly cost twice our highest projection. Mass optimization illustrated by other concept and pilot cars (the Ultralite is far from the lightest yet built, as the authors claim) could further cut costs—enough, we found, to compete with steel unibodies.

Moreover, we assumed an annual production volume of 100,000 vehicles per model. The authors claim that's low. However, the market suggests otherwise: 25 percent of U.S. cars sold are made at lower volumes. That percentage would be higher absent the automakers' focus on amortiz-

ing costly tooling for steel cars. MIT's International Motor Vehicle Program ascribes much Japanese success to ever smaller, more nimble runs that enhance customer choice and reduce financial risk. Composites nicely fit this approach.

Success in the highly competitive global car market demands boldness, not incrementalism, no matter which body material is used. Faster product cycles, lower capital intensity, agile manufacturing, and whole-system design are vital to corporate survival. They're inherent in each new material Field and Clark mention, including high-strength steel. Yet the authors misrepresent lightweight-metal options as incremental and composite ones as radical.

Cost and manufacturability are empirical questions. Some 25 firms have already bet large sums that advanced-composite ultralights—as industry doyen Robert Cumberford predicted in *Automobile* (October/November 1996)—will make them rich. With GM publicly announcing halved-weight-and-drag hybrid-electric-car development and Toyota leaking word of a Corolla-class, 80-mpg hybrid costing approximately $22,500 supposedly slated for volume sales in Japan later this year, we won't have to wait long to see how lightweight cars fare.

AMORY B. LOVINS
MICHAEL M. BRYLAWSKI
DAVID R. CRAMER
The Hypercar Center
Rocky Mountain Institute
Snowmass, Colo.

Field and Clark are out of touch with some of the car companies' aluminum-intensive activities. Whereas the authors claim that Ford is developing 20–40 all-aluminum Taurus sedans, this effort was completed two years ago and 20 of the sedans are now being used regularly by Ford's partners in the project. These vehicles weigh 381 pounds less than the standard steel car. Furthermore, Ford equipped several vehicles in its test fleet with lighter power trains, almost doubling the weight savings. The GM EV1 also uses an aluminum unibody. It is important to note that today's aluminum structures outperform any existing steel structure, owing to their light weight, high torsional rigidity, and crashworthiness.

The article also includes several other misunderstandings:

- Contrary to the authors' assertion, there is absolutely no problem in shaping aluminum into the structural panels that compose unibodies or into the internal panels for space frames.
- The average weight of cars has fallen from about 3,900 to 3,200 pounds, not from 3,500 to 2,500 pounds as the authors claim. In fact, today's Chevrolet Cavalier, a popular *small* car, weighs 2,795 pounds.
- The density of aluminum is 34 percent that of steel, not 45 percent.
- Aluminum (and steel) do melt at the joining surfaces during spot welding to form cast nuggets; it is not a diffusion-bonding process.
- The welding time for aluminum is shorter, not longer, than for steel, owing to aluminum's higher thermal conductivity.
- At just half the weight, aluminum provides the same crash-energy absorption as steel.

M.J. WHEELER
Director of Research
Alcan International Limited
Kingston, Ontario, Canada

Field and Clark erroneously call Ford's joint effort with aluminum companies to produce all-aluminum Taurus sedans "Concept 2000." In fact, the project is known as the Aluminum Intensive Vehicle Program. The project was not "intended only as a test of manufacturability." The resulting vehicles, which were made with aluminum body structures and closure panels that were 400 pounds lighter than traditional components, were subjected to a full range of testing, including crash and durability. That these vehicles performed as well as or better than steel vehicles is a clear indication that lightweight cars can be designed to be crashworthy. Therefore, the authors' claim that "a lightweight car cannot rely on its structural compo-

nents to protect passengers in the event of a crash and so will need to employ additional systems, like airbags, which add some weight," is inaccurate. In fact, one of the functions of the vehicle structure is to absorb crash energy by collapsing in a controlled way. Airbags and other occupant-restraint devices do play a vital role in protecting passengers, but they cannot replace the role of the vehicle structure in a crash.

Field and Clark assert that weight reduction in automobiles has been mostly accomplished by downsizing, and that engineers are reluctant to experiment with new materials. Actually, the evidence is to the contrary. For example, since 1975, the weight of aluminum per vehicle has increased by a factor of 2.5 to about 250 pounds per car. During that same period the use of other weight-saving materials has also grown: plastics have increased by a factor of more than two, magnesium is experiencing double-digit growth, and high-strength steel has tripled and now represents 20–25 percent of the typical body structure. Overall, lightweight materials compose 30 percent of today's average vehicle. This trend will surely continue as development programs, including PNGV, improve the technical and economic feasibility of lightweight materials.

ANDREW M. SHERMAN
Senior Staff Technical Specialist
Ford Research Laboratory
Dearborn, Mich.

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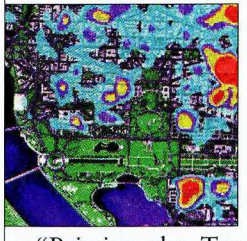
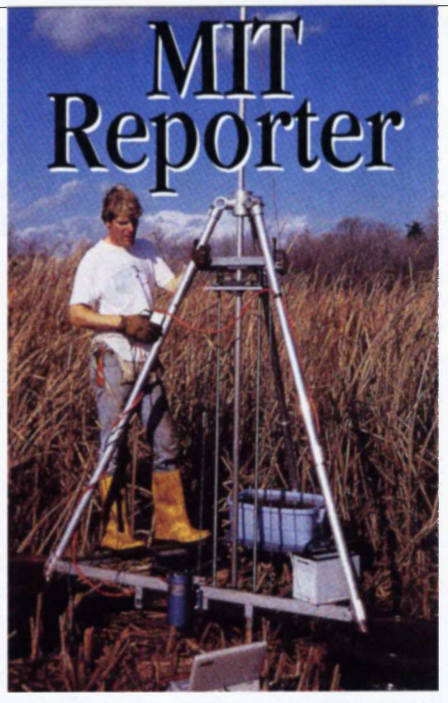
CORRECTION



We neglected to credit Systems for World Surveillance, Inc. (e-mail: sws @rsat.com), for a photograph that appeared in "Painting the Town White—and Green" *(page 54, TR February/March 1997)*. We regret the omission.

MIT Reporter

Arsenic and Old Waste



Researchers studying how arsenic travels through the environment have developed this instrument that quickly identifies different layers of soil and sediment, partly by inducing and measuring changes in water pressure. The information can suggest preferred pathways for water laced with arsenic.

Arsenic has a bad reputation—for good reason. In part, it's a potent poison, as everyone familiar with murder mysteries knows. But while it's rarely used as a weapon in the real world, it does turn up as a contaminant in the environment—and mere traces of the stuff ingested from, say, water, can eventually lead to cancer. Arsenic taints more than 700 hazardous-waste sites across the nation, including lakes and rivers in or near many major cities. Typically the toxin comes from waste dumped decades ago by manufacturers of insecticides and other chemicals.

The question becomes what to do with sites contaminated with arsenic—a metal that can combine with oxygen, carbon, and other elements into various compounds, some that are more toxic and that travel more easily through the environment than others and hence are more likely to be ingested. Ideally, health officials would like to remove arsenic from water and soil. At the least, they'd like to minimize its exposure to humans. But neither can be adequately accomplished until researchers learn the basics of how arsenic moves in the environment and how compounds containing it change over time.

Harry Hemond, a professor of civil and environmental engineering at MIT, has been examining such matters for almost 10 years. Hemond, who also directs the Ralph M. Parsons Laboratory, which conducts studies in water resources and environmental engineering at MIT, has been researching arsenic in the Aberjona Watershed, a 25-square-mile polluted stretch of water north of Boston.

In this aquatic ecosystem Hemond finds that arsenic often cycles between two compounds. One, arsenite, is a highly toxic substance that dissolves and moves easily in water and that humans can thus ingest. The other, arsenate, is a less soluble and less toxic variety that iron-rich particles tend to absorb before settling deep in lake sediments.

Factors such as temperature, dissolved oxygen, organic matter, and microbe populations determine the relative proportions of arsenate and arsenite in water, Hemond says. He and his students have therefore been sampling lakes in the watershed under many conditions.

The group is constantly developing new techniques to obtain results that are as accurate as possible. For instance, David B. Senn, an environmental-engineering doctoral student, has designed a pump to collect and filter water samples from murky, oxygen-free lake bottoms without introducing any oxygen. Because the highly toxic arsenite differs chiefly from its chemical cousin arsenate in containing less oxygen, any addition of that element could lead to unrealistically high readings of the safer compound. Typically, water-filtering devices allow some air—and hence oxygen—to enter the samples. But Senn's apparatus starts out filled with nitrogen. That physically prevents any arsenic-oxygen reactions when researchers introduce lake water into the instrument. The fact that the MIT device filters below the water surface rather than in a laboratory, as is the norm, also helps, Hemond explains.

Through its years of sampling work Hemond's group has discovered that arsenic levels in bottom waters can change dramatically. In 1992 and 1994, the team found roughly the same amount of arsenic along the bottom of a lake that receives Aberjona drainage. But sediment levels skyrocketed in 1993. Thus, says Hemond, health researchers can't "just grab one sample" to analyze an area's level of contamination. The fluctuations could reflect the activity of organisms that absorb and release the metal, he suggests.

Indeed, Hemond's group has discovered that bacteria play a major role in converting arsenate to arsenite. In 1994, then-graduate student Dianne Ahmann—now an assistant professor of microbial ecology at Duke University—and François Morel, a professor of geochemistry at Princeton University, found in sediment samples a bacterium that takes up arsenate, uses its oxygen for energy, and releases arsenite. Ahmann's lab is studying the potential of the microbe, named MIT-13, for remediating arsenic-laden sites so that technicians do not have to excavate large quantities of contaminated soil. Engineers might be able to treat small, isolated areas with MIT-13 to mobilize the arsenic. Although that would result in a more toxic compound, engineers could then pump it out and purify it for reuse in chemicals employed in industries that today are subject to tight environmental regulations. Or engineers could pump out, concentrate, and dispose of the arsenic in designated landfills.

Meanwhile, Hemond's lab, in its continuing quest to catalog environmental factors that influence arsenic, has started investigating other life forms and physical processes that may affect the pollutant. For example, Laurel Schaider, an undergraduate student in environmental-engineering science at MIT, is working to cull from sediment a bacterium that is apparently converting the more toxic arsenite to arsenate. Hemond says that beyond identifying the species, determining how quickly it oxidizes arsenite and how it can grow are necessary steps for indicating whether it could be a catalyst useful in a "low-cost arsenic removal system for small villages" where drinking water contains the metal.

—*Kathryn S. Brown*

PHOTO: PARSON'S LABORATORY

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Trends

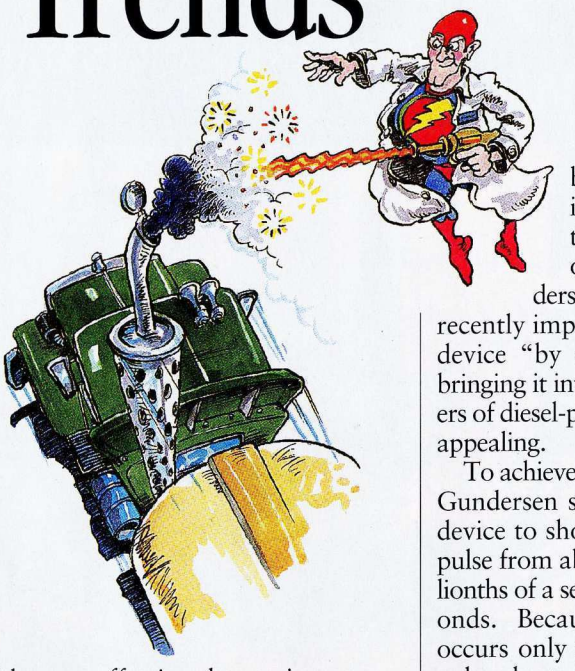
High-Tech Help for Dirty Diesels

Driving behind a bus or truck as it belches smelly exhaust fumes is enough to convince anyone that emissions from diesel engines should be cleaned up. But while gasoline-engine manufacturers have reduced harmful emissions in their new vehicles by some 90 percent over the past 25 years, makers of diesel engines have thus far managed to reduce noxious exhaust fumes by only about half that percentage.

Now, however, researchers at the University of Southern California are developing a device that uses high-energy electrons to zap noxious diesel exhaust, reducing it to water vapor, carbon dioxide, and air. Within a few years, the technique may prove to be a cost-effective way to bring diesel engines into compliance with ever more stringent emissions standards.

According to the Environmental Protection Agency (EPA), heavy-duty diesel engines produce 25 percent of all vehicle-generated nitrogen oxides (NO_x)—the source of nitric acid (HNO_3), a main component of acid rain and a major source of urban smog. Though the first comprehensive federal regulations controlling the emissions of motorized vehicles were initiated under the Clean Air Act of 1970, the first NO_x standards specifically for diesel emissions did not go into effect until 1984. Then, when air quality continued to worsen from increased traffic, Congress passed the Clean Air Act of 1990, which forced manufacturers of trucks and buses to reduce NO_x emissions by 50 percent relative to the 1984 standard. Finally, in 1995, the EPA, in concert with the California Air Resources Board and producers of heavy-duty engines, drafted a statement of principles that led the EPA to set the latest standards aimed at cutting diesel NO_x emissions another 50 percent by 2004.

Diesel engineers have thus far reduced emissions largely by replacing mechanical air-intake and fuel-delivery controls



with more effective electronic systems. Now researchers, including Martin Gundersen and Victor Puchkarev, a pair of electrical engineers at the University of Southern California, are exploring exhaust after-treatment systems. Based on a "pulsed-power" electronic circuit that originated in the 1950s and was refined during work on the Strategic Defense Initiative in the 1980s, their device uses short bursts of high-energy electrons to break down NO_x and other sooty particulates in diesel exhaust before they make their way to the atmosphere.

The USC group has developed a chamber that can be incorporated into a diesel-exhaust system much like a catalytic converter is used in gasoline-powered vehicles. Inside the chamber, a special electronic switch produces a short electrical pulse, like the burst from a camera's electronic flash attachment, at the rate of thousands of electrical discharges per second. When energetic electrons from these rapid-fire high-voltage sparks are injected into the exhaust stream, similar to the way an electron beam is fired into a fluorescent tube, they strike air and water vapor molecules present in the exhaust. The collisions create an ion plasma—an assortment of electrons and charged particles of nitrogen, oxygen, and hydroxide—which, in turn, reacts with NO_x and particulate hydrocarbons to produce carbon dioxide, air, and water vapor.

Early prototypes proved the concept but were inefficient, requiring as much as 50 percent of the engine's power for their operation. However, Gundersen claims that the team has recently improved the efficiency of the device "by an order of magnitude," bringing it into a range that manufacturers of diesel-powered vehicles would find appealing.

To achieve the dramatic improvement, Gundersen says his team tweaked the device to shorten the duration of each pulse from about 200 nanoseconds (billionths of a second) to about 50 nanoseconds. Because electron acceleration occurs only in the initial stages of the pulse, shortening the bursts raised the energy of the electrons in the plasma while consuming much less energy overall.

According to Bernard M. Penetrante, a physicist who heads the Environmental Plasma Technologies group at Lawrence Livermore National Laboratory, a dozen or more groups worldwide are now engaged in similar R&D work that may eventually compete for a share of a huge potential market. Indeed, the EPA estimates that some 5 million heavy-duty and 2 million light-duty diesel vehicles now roll along U.S. roads, and that several hundred thousand new diesel vehicles are sold in the country each year.

Gundersen estimates that a pulsed-power after-treatment device would cost on the order of $1,000. If that proves to be the case, the market could easily be worth several billion dollars. And the market may not be limited to diesel engines. Penetrante notes that any device that can reduce NO_x to benign products in a diesel exhaust pipe can also be applied to gasoline engines. He explains that similar conditions exist in new lean-burn (high air-to-fuel ratio) gasoline engines, and that new technologies such as pulsed power will be critical for allowing the next-generation vehicles to meet ever-stricter emissions requirements.

—*Laura Jean Penvenne*

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ILLUSTRATION: JON McINTOSH

Repairing Severed Spinal Cords

With its army of cells and myriad antibodies, our immune system is well designed to repel attacks by harmful bacteria, viruses, and other microbes. But it may also hold a key to a long-standing mystery—how to treat spinal-cord injuries that each year leave thousands of people paralyzed. A well-known example is the unfortunate outcome of actor Christopher Reeve's fall from a horse.

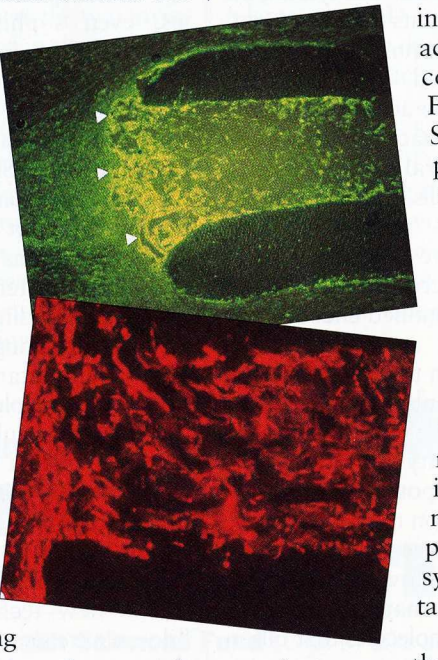
The hope for new treatments stems from recent research on macrophages—immune cells that are among the first to arrive on the scene when the body suffers a wound or infection. Drawn by chemicals released at the damaged area, macrophages rush to sites of inflammation and act like cellular vacuum cleaners, ingesting invading microorganisms, dead or dying cells, and any other debris.

This clean-up work is essential because it allows the body to repair a wound efficiently. If you think of a wound site as a pothole in the street, the job of macrophages is to remove any pieces of crumbled pavement before the hole gets filled in.

Yet growing evidence suggests that the human central nervous system—the brain and spinal cord—denies itself the healing touch of these immune cells. While macrophages do not normally exist in the central nervous system, they should seemingly be able to migrate there when beckoned by inflammatory chemicals. Several years ago, however, researchers began to show that few macrophages respond to brain or spinal-cord injuries.

Following up on that lead, a research team led by Michal Schwartz of Israel's Weizmann Institute of Science has recently found that the mammalian central nervous system secretes a molecule that inhibits the recruitment and activity of macrophages. According to Schwartz, the molecule, which the researchers have yet to name, also restrains microglia—cells in the brain that appear to closely monitor the health of neurons and transform themselves into macrophages in response to certain stimuli.

Why would our central nervous system possess the means to inhibit the normally helpful immune system? Schwartz speculates that exerting control over macrophages is vital if the mammalian brain is to prevent inadvertent destruction of its intricate neural circuits. She notes that macrophages are indiscriminate eaters, sometimes devouring healthy cells at a wound site as easily as bacteria and dead cells. In most tissues, that's a reasonable tradeoff to guarantee that a wound is properly cleaned. In the brain and spinal cord, however, any loss of cells might be disastrous. So Schwartz believes that the central nervous system eliminated the risk that macrophages might mistakenly harm it by developing agents that suppress the cells. "It's a benefit for the healthy brain," she says, "but it's a drawback when there's an injury."



When researchers severed rat spinal cords by inserting special tubes into the spinal column (top), local immune cells called macrophages (shown in yellow) wandered into the resulting gap but did little to repair the damage. When the tubes contained macrophages from other parts of the body, however, these cells triggered dramatic regrowth of nerves and blood vessels (bottom).

Schwartz contends that the suppression of these immune cells underlies the well-documented inability of the human spinal cord to repair itself. In a spinal cord injury, a person remains paralyzed because the cord's axons, the long cables that link one nerve cell to another, do not regenerate when crushed or severed. Damaged nerve cells do send out new extensions, but growth of these fledgling axons quickly stalls.

Why spinal cord axons in humans fail to fully regenerate, while axons in arms and legs and elsewhere in our peripheral nervous system do so with relative ease, has long been a frustrating mystery. For decades, scientists simply thought mammalian spinal cords did not have the ability to repair axons. A consensus has recently emerged that axons in the central nervous system can indeed regenerate but that substances in their environment actively thwart their complete regrowth. For example, besides Schwartz's macrophage-inhibiting molecule, the central nervous system contains a type of myelin—the fatty insulation surrounding axons—that includes at least one protein that directly stops a regenerating axon in its tracks. Curiously, myelin from the peripheral nervous system does not contain this protein.

Schwartz maintains that macrophages are needed to efficiently clean up loose myelin, which harbors the axon-inhibitory protein, and other materials that pervade the site of a spinal cord injury. In recent experiments on rats, Schwartz's group tested the therapeutic powers of macrophages on severed optic nerves, the thick bundles of axons that transmit information between the eye's retina and the brain. Investigators work with optic nerves because they match spinal cords in their inability to regenerate axons after an injury and can be monitored more easily. Last fall, Schwartz's group reported that macrophages placed at the

PHOTOS: ALEXANDER RABCHEVSKY

site of a rat's severed optic nerve spurred the regrowth of new axons across the lesion.

The challenge was to trigger the macrophages, which normally exist in a quiescent state, to enter their wound-healing vacuum-cleaner mode. The researchers found that when the immune cells were first grown in the laboratory with tissue from the rats' central nervous system, the macrophage transplants failed, presumably because the immune-suppressing molecule discovered by Schwartz's group prevented the activation of the cells. But when macrophages were grown with peripheral nerve segments, transplants of the cells stimulated axons to regenerate.

Scientists who have conducted similar experiments on the crushed spinal cords of rats have also obtained encouraging results. "We took activated macrophages, put them in the injured spinal cord, and found enhanced regeneration," says Wolfgang Streit, a neuroscientist at the University of Florida Brain Institute. Streit proposes that the macrophages, in addition to their clean-up functions, may prepare paths for growing axons by laying down components of the extracellular matrix, a mesh of proteins and other molecules that fills in the space between cells.

Though the early findings have been tantalizing, using macrophage transplants to treat spinal cord injuries is a strategy still in its infancy. The next critical step is to prove that the spinal-cord axons that regenerate after macrophage therapy can actually restore function to paralyzed limbs. Both Streit and Schwartz are already conducting animal studies to explore that question.

Although such evidence is not yet in hand, researchers are optimistic that macrophage-transplant therapy will become part of the arsenal physicians use to treat damaged spines. "The question is no longer whether spinal cord axons can regenerate," says Wise Young, a spinal-cord injury investigator at New York University, "but how we can get them to regrow much more efficiently."

—*JOHN TRAVIS*

An Added Dimension in Display Technology

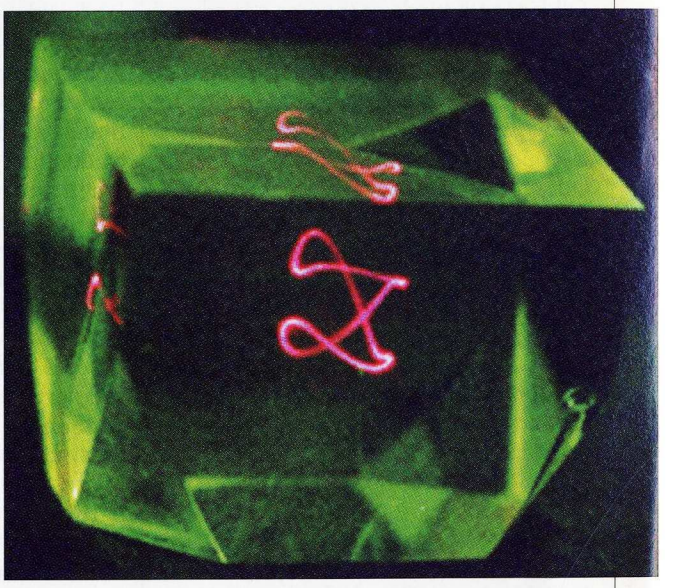
While we see in 3D, most pictures exist only in 2D. Even clever attempts to make convincing three-dimensional representations of objects—Victorian-era stereoscopes, green-and-red-lensed spectacles for 1950s B movies, even sophisticated holographic images—all strain to create the illusion of three dimensions on a two-dimensional surface.

Now Elizabeth Downing, a former Stanford University graduate engineering student turned entrepreneur, has taken a completely different approach by building a true 3D display. Though small and rudimentary, her proof-of-principle invention—a sugar-cube-sized block of special glass—can come alive with dancing colors that exhibit height, width, and, most importantly, depth.

The new technology "doesn't create an image that appears to be three-dimensional," Downing says, "it actually produces an image that is drawn in three dimensions." As a result, it places few restrictions on the viewing angle or the number of people who can observe the images at the same time. Moreover, the images are emissive—they glow rather than reflect—so viewers can easily see them under ordinary room light without special glasses or headgear.

The display's unique characteristics seem to make it a natural for potential use in, for example, medical diagnostic-imaging systems, arcade games, computer-aided-design tools, and air-traffic-control monitors. The display could also be employed as a scientific-visualization aid for analyzing weather patterns, air flows around an aircraft, and other complex multidimensional sets of data.

The patented device, now being commercialized by Downing's new company, 3D Technology Laboratories of Mountain View, Calif., uses a pair of infrared lasers to selectively excite fluorescent metallic particles suspended in a clear glass cube, measuring 1.5 centimeters on a side. When these special rare-earth metal additives (also called dopants) are mixed into the molten glass during manufacturing, they "distribute themselves evenly throughout the glass like chocolate chips in a cookie," Downing says. When a spot inside the solidified glass is illuminated with invisible infrared light, the tiny impurities glow brightly.



By shooting infrared lasers at tiny fluorescent metal particles in this sugar-cube-sized block of glass, a former Stanford engineering student creates brightly glowing images that convey scientific information in three dimensions.

The ability to visualize real-time volumetric data in true three-dimensional form has been the Holy Grail of display-development efforts for decades. And while the concept of depicting 3D objects in fluorescent glass dates back at least to the mid-1960s, not until the early 1970s did researchers at Battelle Laboratories in

IMAGE: 3D TECHNOLOGY LABORATORIES

Columbus, Ohio, succeed in generating two faint dots of light inside a crystal of erbium-doped calcium fluoride using high-intensity light from xenon lamps, similar to that generated by halogen sources. But that was as far as they got.

Realizing that inexpensive but powerful lasers and new optical materials had since become available, Downing, working as an engineer on laser-based equipment at FMC Corp.'s Technology Center in Santa Clara, Calif., believed the time to develop the technology was at hand. When she came to Stanford for further graduate studies in 1988, she continued her research on 3D displays with Lambertus Hesselink, a professor of electrical engineering at the university, receiving a $350,000 U.S. Navy grant and additional support from the Defense Advanced Research Projects Agency to pursue the concept.

The prototype display she developed is based on a principle called "upconversion." Certain rare-earth elements exhibit this phenomenon by emitting visible light when struck in quick succession by two infrared laser beams of given wavelengths. Neither beam has enough energy to cause fluorescence by itself, Downing explains, but the combined energy of the two can cause an ion in the glass to glow.

When the ion, which normally remains at its lowest energy level, absorbs energy from the first laser, it makes a transition to an intermediate excited phase, where it remains for a short time. When an ion in this phase is struck by the second laser beam it absorbs energy at the second wavelength, undergoes a transition to an even more excited state, and re-emits most of its excess energy as a single photon of visible light as it decays back to its ground state.

To enable the prototype display to produce color images, Downing assembled the small glass cube from three layers of fluoride glass developed for commercial fiber-optic lasers and optical amplifiers. Each layer contains ions that emit one of the three additive primary colors—a layer doped with praesodymium glows red, another with erbium glows green, and a third with thullium glows blue.

Downing assigned addresses to precise points on each glass layer. Then by programming a pair of laser scanners she borrowed from optical disk players, she was able to direct the laser beams vertically and horizontally as well as backward and forward through the cube. By controlling exactly where the two invisible laser beams crossed in the transparent glass, she was able to light up a fluorescent additive of a given color—much like an electron beam lights up particular phosphors on a color television screen—to produce the desired image.

Each turned-on point of light—called a volume element, or voxel—is like a World War II bomber caught in the intersection of two searchlight beams. However, voxels are tiny. In fact, beams focused to a diameter of 100 microns, produce roughly 300 voxels around the perimeter of a circle one centimeter in diameter.

The display in Downing's initial prototype is composed of a stack of only three individual glass layers glued together with an optically compatible adhesive to form a composite structure. However, the inventor intends to build a larger-scale 3D color system by assembling many thin doped layers arranged in a repeated sequence—red, blue, green; red, blue, green; and so on—to enable the creation of high-resolution color images. In fact, Downing has already begun evaluating new display materials and has started work on her next project (for which she says she has received venture-capital funding): building a display using a 6-inch glass cube.

—*JOHN DRAKE*

CityLab, a fully equipped biotechnology laboratory at Boston University, allows visiting students to use sophisticated techniques to solve real problems. The creators of the program are now putting the program on wheels to reach a wider audience, outfitting a school bus with 20 high-tech workstations (below).

Have Lab, Will Travel

Remember the bookmobile—the friendly traveling emissary from the local library whose mission was to interest kids in reading by bringing books to them at school? Now two professors at Boston University are reviving the concept with an updated mission: to expose students to state-of-the-art laboratory techniques in biomedical sciences.

Toward this end, Connie Phillips, an assistant research professor with nearly two decades of experience teaching biology to undergraduates and high school students, and Carl Franzblau, associate dean for medical sciences and chair of the biochemistry department, are outfitting a mobile lab with all the equipment needed to conduct a full range of experiments in modern molecular biology and genetic engineering. Workstations in a 40-foot, custom-designed school bus with room for 20 students contain all the accoutrements found in a modern lab, from test tubes and pipettes to incubators and spectrophotometers. The mobile unit will travel to high schools and middle schools throughout the Boston area to augment the students' biology classes.

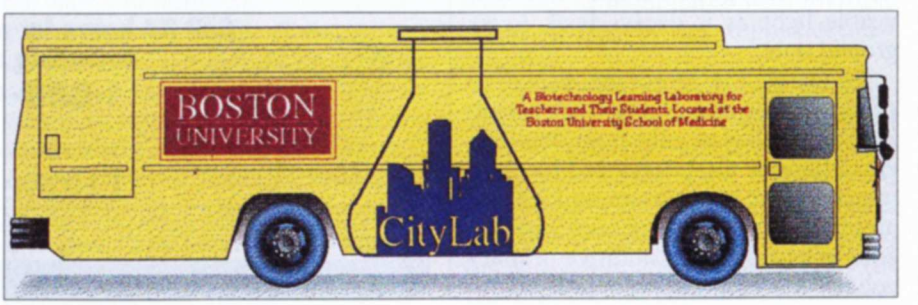
"Our aim is to provide access to laboratory facilities and hands-on biotechnology learning otherwise unavailable to most school systems," says Phillips. "We're seeing an enormous gap between the type of equipment and techniques high-school students are normally exposed to and those used in modern research," she says. "Unfortunately, it's just not practical to outfit all our public high schools with this kind of specialized and expensive equipment."

Phillips and Franzblau's mobile lab builds upon their overwhelming success in a similar effort called CityLab, a stationary facility at the Boston University School of Medicine that now serves as a fully equipped regional biotechnology resource for middle and high schools. Since it was founded in 1991, CityLab has increased its capacity to 50 students per day throughout the school year and is still booked a year in advance. So far more than 10,000 students and 1,000 teachers have visited the lab to participate in the day-long curriculum.

CityLab challenges students to solve mysteries by applying the concepts used in modern biology laboratories. In preparation for their visit, students are grouped into teams, presented with the mystery they will work to solve, and, with the aid of their teacher, offer preliminary ideas about the problems. When they reach the lab, they can apply the latest high-tech procedures to find the solution. In the "mystery of the crooked cell," for instance, students, acting as medical researchers, determine whether their patient has sickle cell anemia by using electrophoresis, which separates red blood cells according to size in order to differentiate sickle cells from normal hemoglobin. In another module, the students find the perpetrator of a crime by using DNA fingerprinting techniques.

Phillips says the CityLab program grew out of summer workshops she and Franzblau offered in the late 1980s at Boston University School of Medicine to high-school science teachers who sought to update their knowledge of procedures in the fast-changing biotechnology field. The teachers were inspired by the workshops, Phillips says, but they "complained they had no place to teach the exciting things they were learning about. We wanted to respond to that need."

By all accounts, however, the team didn't realize how widespread the interest in their program would be. "We never expected the flood of inquiries from all over or the one-year waiting list despite our efforts to expand the program," Franzblau says. So far, several area public schools have lauded CityLab, and the nearby Cambridge and Quincy public schools have made the program an official part of their seventh- and



PHOTOS: BOSTON UNIVERSITY SCHOOL OF MEDICINE; OHIO BUS SALES

eighth-grade curricula. CityLab has also spawned satellite programs around New England and as far away as Alaska and Glasgow, Scotland.

Unfortunately, though, as Phillips notes, even organizing a day-long field trip is beyond the capacity and budget of many schools. The CityLab team wanted to make the laboratory experience even more accessible and had thought for several years, Phillips says, about the possibility of "putting it on wheels." In part to offer more capacity and in hopes of reaching a greater diversity of students, the team created the mobile lab. "It can pull into the parking lot and the students can march out and get right on the bus," she says. "We're hoping the sheer availability will help us reach a lot of new teachers and students," she says. Moreover, Franzblau notes, the accessibility offered by a mobile laboratory means students won't have to take a full day off to use its resources; various classes can spend shorter periods in the lab.

Starved for resources, science teachers in underfunded public-high-school systems might well be attracted to a mobile lab program. But that initial impetus can't fully explain the popularity of the program among students. Phillips stresses that students find the authenticity of the lab exciting. "They recognize the fact that some of the equipment is expensive and specialized, and they show a tremendous amount of respect," she says, adding that in all the years she has run the CityLab program she has never seen even one instance of vandalism. "I think students pick up on the fact that this is the real thing," she says. And the design of the curriculum gives students a reason for being in the lab and a serious job to perform.

The best part, though, Phillips says, is that the experience is not just authentic but also accessible. "Students often realize that molecular biology is do-able, that you don't have to be really brilliant to do this work". As Franzblau puts it, "If we get even a small subset of students stimulated, we feel we've accomplished something important."

Franzblau doesn't hesitate to forecast further expansion. If the mobile lab proves successful, he says, a fleet of three or so could rotate to cover a wider range of Boston-area schools. And he's excited at the prospect that satellite lab programs around the country can build on the team's curriculum and share experiences. "The need is there," he says. "Every urban area from Atlanta to Seattle should have one".

—*SETH SHULMAN*

DATA SMOG

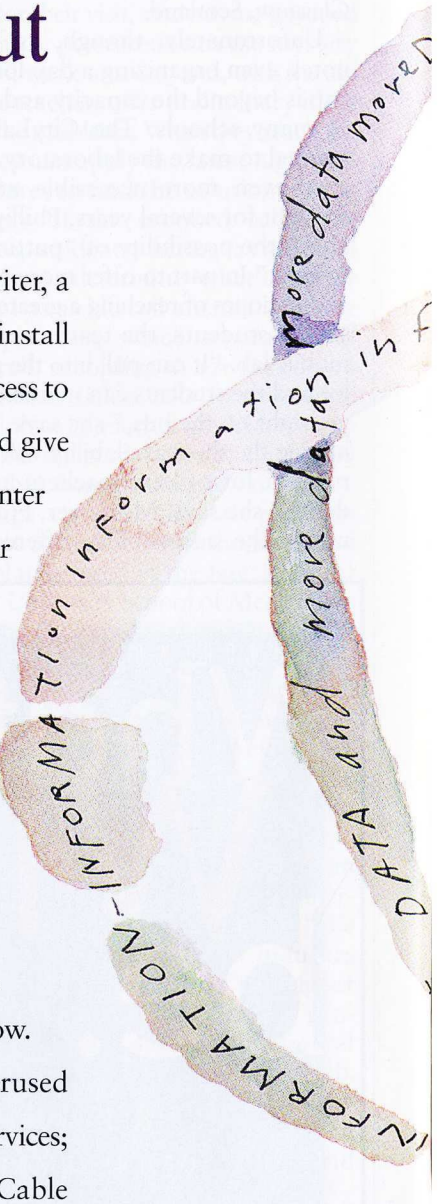
Surviving the Info Glut

BY DAVID SHENK

DURING the infancy of my career as a freelance writer, a man came to my home in Washington, D.C., to install a prolific new appliance. The machine gave me access to the Federal News Service, which I felt sure would give me a leg up. Every day, morning, noon, and night, the printer spat out interviews from talk shows only moments after they had been broadcast, major speeches from senators, ambassadors, and other Washington heavies, and absolutely every utterance from the White House. Without ever leaving my home office, I felt plugged in.

The ability to churn out ever greater volumes of information in a variety of formats has exceeded our ability to process it. Fortunately, firm action, both personal and political, can help clear the air.

The installation resulted from my decision to confront the rushing tide head on, to try to keep pace with the new and speedy, and to more or less disregard the old and slow. As part of this approach I doggedly perused numerous newspapers, magazines, and wire services; I continually checked my e-mail; I watched Cable News Network; I stopped spending time with books and other cumbersome material that felt more like yesterday.



ILLUSTRATIONS BY BLAIR THORNLEY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MORE NUMBERS AND WORDS
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But I soon found that my reliable Federal News Service printer expected me to be its equal. It could print two pages a minute—why couldn't I read two pages a minute? The printer had just spewed out a dozen transcripts. Was I still working on that same paragraph?

Somewhere along the line, the empowering eagle became an albatross. In a month or so, I pulled the plug. The nice man came back and carted the machine away. I locked the gate behind him.

Some years later, in a classroom at Columbia University, I attended a guest lecture given by Brian Lamb, sometime anchor of the two C-SPAN channels, which broadcast congressional debates and other government proceedings. For an hour or so, Lamb spoke confidently about the history of C-SPAN and why he believed it to be a vital public service. He boasted of his plans to introduce the new cable channels C-SPAN3, C-SPAN4, and C-SPAN5. But then his host, Columbia economics professor and communications specialist Eli Noam, asked Lamb two simple questions: "Is more information necessarily good? Does it really improve the political process?"

"I haven't got a clue as to whether it's good or bad," Lamb replied. "But you can't stop this process. It's the American way. Which part of the library or the Internet do you want to shut down?

At home, at work, and even at play, communication has engulfed our lives. To be human is to traffic in enormous chunks of data. "Tens of thousands of words daily pulse through our beleaguered brains," says philosopher Philip Novak, "accompanied by a massive amount of other auditory and visual stimuli. No wonder we feel burnt."

If the concept of too much information seems odd and vaguely inhuman, that's because, in evolutionary-historical terms, it is. For 100,000 years people have been able to examine and consider information about as quickly as they have been able to create and circulate it. A range of communication technologies from the drum and smoke signal to the telegraph and telephone enabled us to develop and sustain culture and overcome our fear of others, diminishing the likelihood of conflict. But in the middle of this century the introduction of computers, microwave transmissions, television, and satellites abruptly knocked this graceful synchrony off track. These hyper-production and hyper-distribution mechanisms have surged ahead and left us with a permanent processing deficit—what Finnish sociologist Jaako Lehtonen calls an "information discrepancy."

In 1850, 4 percent of American workers handled information for a living; now most do, and information processing, as opposed to manufacturing material goods, now accounts for more than half the U.S. gross national product. Information has become so ubiquitous partly because producing, manipulating, and disseminating information has become cheap and easy; with a thumb and index finger, we effortlessly copy and paste sentences, paragraphs, books, and "carbon copy" e-mail to one or one hundred others.

We crave and pay handsomely for some of the information we receive—the seductive, mesmerizing quick-cut television ads and the 24-hour up-to-the-minute news flashes. It arrives in the form of the faxes we request as well as the ones we don't; we pursue it through the Web sites we eagerly visit before and after dinner, the pile of magazines we pour through every month, and the dozens of channels we flip through whenever we have a free moment.

What is the harm of this incessant barrage of stimuli captivating our senses at virtually every waking moment? "We're exceptional at storing information," explains UCLA memory expert Robert Bjork. "But there are retrieval limitations." Memory is stored according to specific cues—contexts within which the information is experienced. When the contexts begin to vanish in a sea of data, it becomes more difficult to remember any single piece of it. The more we know, the less we know.

"We're pushing ourselves to speeds beyond which it appears we were designed to live," says Nelson Thall, research director at the University of Toronto's Marshall McLuhan Center. "Electric technology speeds up the mind to an extraordinary degree, but the body stays in place. This gap causes a lot of stress."

At a certain level of input the glut becomes a cloud of data smog that no longer adds to our quality of life but instead begins to cultivate stress, confusion, and even ignorance. Information overload crowds out quiet moments and obstructs much-needed contemplation. It spoils conversation, literature, and even entertainment. It leaves us more vulnerable as consumers and less cohesive as a society. "We tend to make very unsophisticated inferences when we're under cognitive load," says University of Texas psychologist Dan Gilbert. "Thinking deeply cannot be done." Since today's glutted environment renders consumers distracted and easily open to suggestion, data smog may just be the best thing to come along for hyperinformed marketers since planned obsolescence.

This isn't the first time we have confronted the unpleasant side effects of abundance. We who live in the most sophisticated and successful nation on earth

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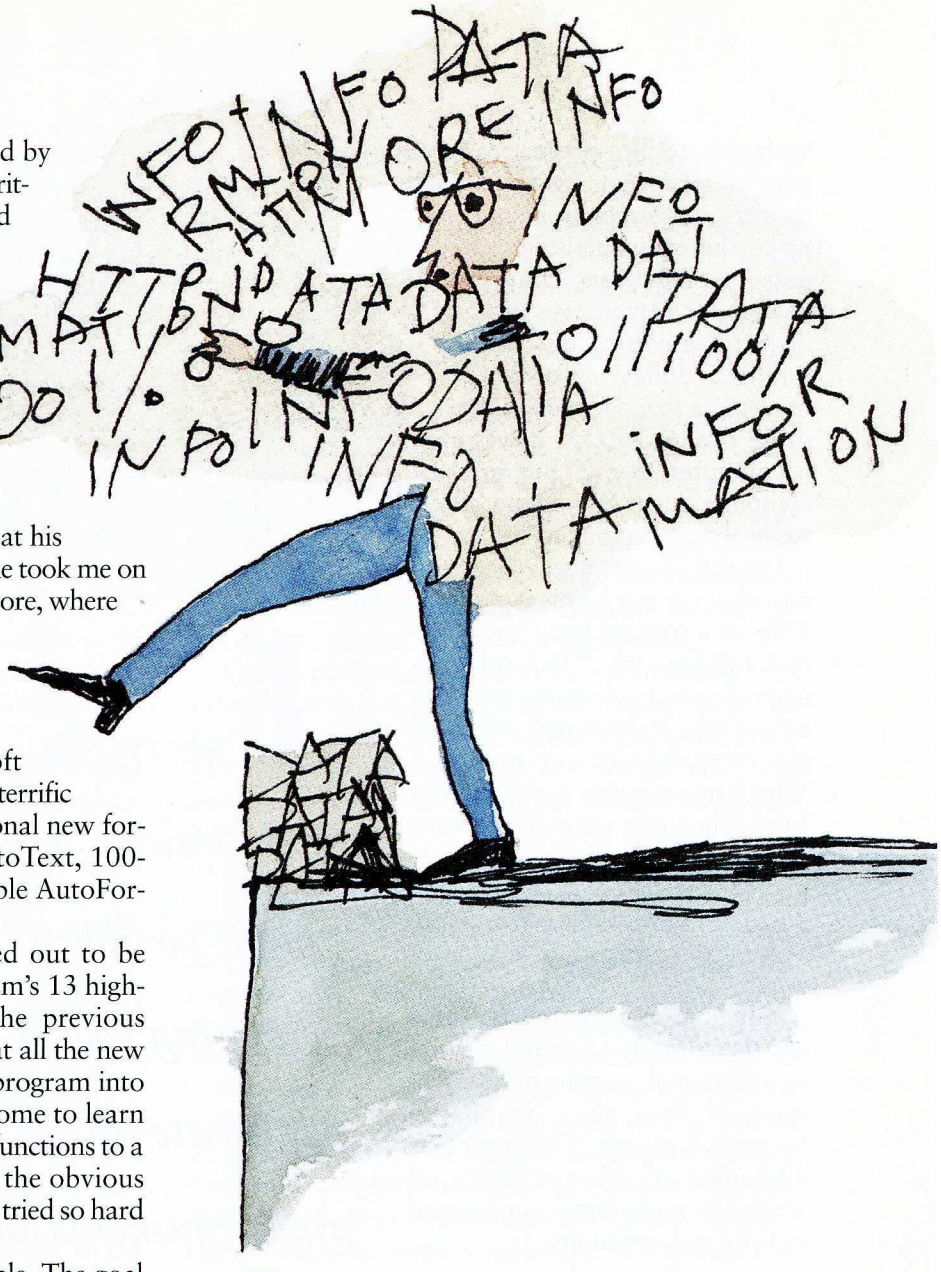
DAVID SHENK, a fellow at the Freedom Forum Media Studies Center in New York from 1995-6, has written for Harper's, Wired, Spy, *and the* Washington Post. *He can be reached at dshenk@bigfoot.com.* *This article is adapted from* Data Smog: Surviving the Info Glut, *published in April by HarperEdge, an imprint of HarperCollins.*

have routinely found ourselves burdened by problems of excess. Now, exploring the critical distinction between information and understanding—and finding some healthful remedies—is one of the most important things we can do.



Peddling Information Anxiety

When I visited an old friend from high school at his office at Microsoft one spring, he took me on a swing through the company store, where employees can buy software for 80 percent off. My eyes darted around maniacally and my pulse raced as I amassed stacks of CD-ROMs and added the latest upgrade of Microsoft Word to the pile. The latter seemed like a terrific bargain as it included dozens of sensational new formatting features like AutoCorrect, AutoText, 100-Level Undo, drag-and-drop editing, Table AutoFormat, and something called Wizards.

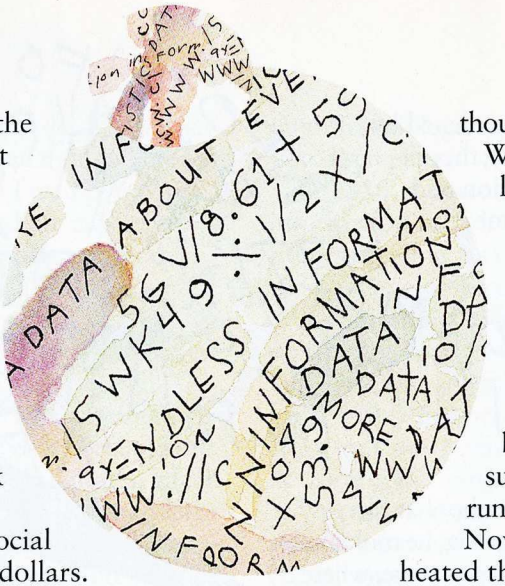
But the bargain on Word 6.0 turned out to be wasted cash. After I installed the program's 13 high-density disks onto my hard drive (the previous upgrade had required just 5), I found that all the new bells and whistles had transformed the program into a zoo of capabilities that were cumbersome to learn and had slowed even the most elemental functions to a painful crawl. The minor fiasco raised the obvious question: if it wasn't broke, why had they tried so hard to fix it?

Mostly because it's terrifically profitable. The goal of the information industry is to convince consumers that, whatever they have, it isn't enough. That strategy reaps billions of dollars every year for programmers, manufacturers, marketers, and public relations professionals. If Windows 95 felt like old news in 1996, that's because Microsoft planned it that way. Since Microsoft makes most of its profits on upgrades, the real product it is selling isn't hardware or software but information anxiety.

It works. At the beginning of this decade, IBM found that people were replacing their computers every five years. By 1995, users were considering their machines obsolete in just two years. What they only yesterday regarded as critical machinery they now saw as useless plastic. Overall, by the year 2005, the nation will have tossed some 150 million computers onto the scrap heap.

Upgrade mania does not come cheap. While personal computers are relatively inexpensive compared

Information overload not only crowds out quiet moments and obstructs contemplation; it also leaves us more vulnerable as consumers and less cohesive as a society.



with their bulky predecessors, the pace of improvements is such that the personal computer habit ends up costing individuals and businesses a significant chunk of change. "Did you ever notice how, for anything else, three hundred dollars is a lot of money?" a friend remarks as we drool over CD-ROM drives in a computer store. "But in the computer universe, we don't think twice about spending it."

Upgrade mania also exacts a social cost that cannot be measured in dollars. "We see a training gap," says Oracle's Bill Seawick. "Technology is coming at such a fantastic pace that people have to learn new technologies every three or four months." What's more, points out economist Juliet Schor, new technology "leads to the expansion of tasks that people are expected to do. We are supposed to improve our performance and output year after year after year."

When Americans tell pollsters and therapists that they feel they are losing control over the basic structures of their lives, it's partly because they are. The ferocious upgrading of the machinery all around us undermines our sense of security and continuity.

The Normalization of Hype

On National Public Radio's "All Things Considered" one evening, reporter Chitra Ragavan is trying to make sense of the latest cancer study, which doesn't mesh with previous analysis. "If you don't have some level of confusion about how to interpret this study," the National Cancer Institute's Philip Taylor tells Ragavan, "you should."

In an era in which limitless data make possible a widening pool of elaborate studies and arguments on every side of every question, political as well as scientific, more expert knowledge has, paradoxically, led to less clarity. Is dioxin as dangerous as we once thought? Do vitamins prevent cancer? Would jobs have been gained or lost under Bill Clinton's comprehensive health care plan?

In an era in which limitless data make possible a widening pool of elaborate studies and arguments on every side of every question, more expert knowledge has, paradoxically, led to less clarity.

Because there is always an opportunity to crunch some more numbers, spin them a bit, and prove the opposite, the winner has become argumentation itself. Factionalism gets a big boost while dialogue and consensus—the marrow of democracy—run thinner and thinner every year.

Nowhere are the stat wars more heated than in Washington, D.C, where supplying grist for endless policy debates has become a significant industry. With purposefully vague and formidable names like Institute for Responsive Government and the National Center for Policy Analysis, hundreds of so-called "think tanks" have popped up to become masters of contention. Shaping the mood of Washington begins with press play, and every think tank has a point person to coordinate the flow of information. "I probably have four to five thousand journalists on my system," estimates Vincent Sollitto of the American Enterprise Institute. "That's just about every journalist in the world. They are cross-referenced in a tier form—national media, regional media, trade press, foreign press, and then cross-referenced by interest code—people interested in the environment, in economics, in other topics."

Public relations agencies profit handsomely from fanning debates, and television shows like "Crossfire" are specifically designed to exploit the entertainment value of the stat-war phenomenon. The charges fly back and forth across the table as furiously as a ping pong ball. But there is no referee and no official scoring; the show always ends before viewers have time to gauge the accuracy of the shots.

The statistical anarchy freezes us in our cerebral tracks: we react to an overabundance of competing expert opinions by simply avoiding coming to conclu-

sions. As the amount of information and number of claims stretches toward infinity, we are on the verge of succumbing to paralysis by analysis.

Inevitably, to attract people's attention, communicators of all types resort to barrier-piercing countermeasures, feeding a vicious spiral in which the data smog gets thicker and thicker and the efforts to cut through the smog ever more desperate. Advertising becomes noisier and more invasive and frequently skirts the bounds of taste. Films become ever more sexually explicit and violent. The basic character of our future information society has already formed: its colors are lighted in a blaze of neon; its audio track is full of expletives, insults, and explosions; and its cultural trademark is the ever-more-outrageous public relations stunt, such as the offer by a San Francisco radio station of a case of Snapple to the family of the one-thousandth person to commit suicide by jumping from the Golden Gate Bridge.

Our society is experiencing what communications scholar Kathleen Hall Jamieson calls "the normalization of hyperbole." The degree to which today's television programmers, movie producers, performers, spokespersons, and publishers apparently feel compelled to turn up the heat is a serious threat to moderation and intelligence. It reduces our attention span. It makes us numb to anything that doesn't lurch out and grab us by the throat.

This effect is one of the main reasons political campaigns have become so acrimonious. The growing mean-spiritedness merely reflects a society where hyperbole, vulgarity, and ostentation thrive. In a Maryland senate race, William Brock III falsely suggested that Ruthann Aron, his opponent in the primary, had been convicted of fraud. Aron sued. In his defense, Brock offered as justification: "Everybody knows there's hyperbole in election campaigns."

Unfortunately, this approach may discourage some of our best minds from entering the public debate. If one has to be sensational and dramatic to gain attention, what does that portend for the insightful minds whose ideas don't lend themselves to MTV or flashy Web pages? If our attention naturally gravitates toward the Madonnas and Howard Sterns of the world, who is left behind in the dust? The normalization of hyperbole suppresses the individuals we most desperately need in our complex times—those who are willing to confront life's ambiguities.

Village of Babel

When I visited James Quello, head of the Federal Communications Commission, in his office to discuss surveys that showed a surprising lack of knowledge about political affairs among the American public, he commented, "If people would just tune in, they'd be better informed." The problem, of course, is that people *are* tuning in but they're acquiring specialized knowledge.

"There is so much information," laments pollster Andrew Kohut, "that people throw their hands up and say, 'Well, I'm going to focus on this very narrow part of the world.'"

A pluralistic democracy requires a certain amount of tolerance and consensus rooted in an ability to agree on common questions. Yet in an electronic world of endless communication choices, we increasingly speak different languages and share fewer metaphors, icons, historical interests, and news events. Bill Gates's celebrated "asynchrony" is but an eloquent way of saying that we are out of step with one another.

This response is one reason for the troubling level of social polarization plaguing the United States. We face a paradoxical spiral in which the more information we come upon, the more we narrow our focus and retreat into different spheres of knowledge. We are, as writer Earl Shorris says, "A nation of lonely molecules."

The Internet promotes this trend. Although 11 billion words on 22 million Web pages give us access to more information than ever before, Web surfers often explore their personal interests, and are often rewarded with highly specific information and communicate only with people who share those interests.

Software enabling us to create "smart agents" that automatically filter out information we don't think we need will further exacerbate this trend: stumbling onto new and interesting subject matter becomes much less likely in a customized information environment. Nicholas Negroponte of the MIT Media Lab insists that smart agents can and should include an adjustable "serendipity dial." But one can not automate spontaneity.

The Internet does allow previously disenfranchised groups to communicate cheaply without geographic limitation. Gays and lesbians, for example, inherently dispersed throughout society, have benefited tremendously from online forums that offer the opportunity to share their thoughts about what it means to be gay, practical considerations about living a healthy, happy life, and techniques for forcing politicians to take them seriously as a group with important interests. But there is a great danger of mistaking cultural tribalism among people with obviously common interests for real, shared understanding among more diverse groups.

Journalists can provide the vital social glue that makes us a common unit, and also help us analyze competing statistical claims. Unfortunately, many journalists reflexively balk at the prospect of stories that smell of "old news," reporting instead the latest opin-

ion poll, the shocking personal indiscretion, this morning's testimony.

The news-flash mindset arose among a group of producers at a weekly editorial meeting I attended years ago for National Public Radio's "Talk of the Nation." One of us had suggested an educational show on AIDS prevention, in light of polls that showed much ignorance on the subject. But both the senior producer and the host quashed the idea, insisting that the information had already been reported and that it was "not our job to educate people."

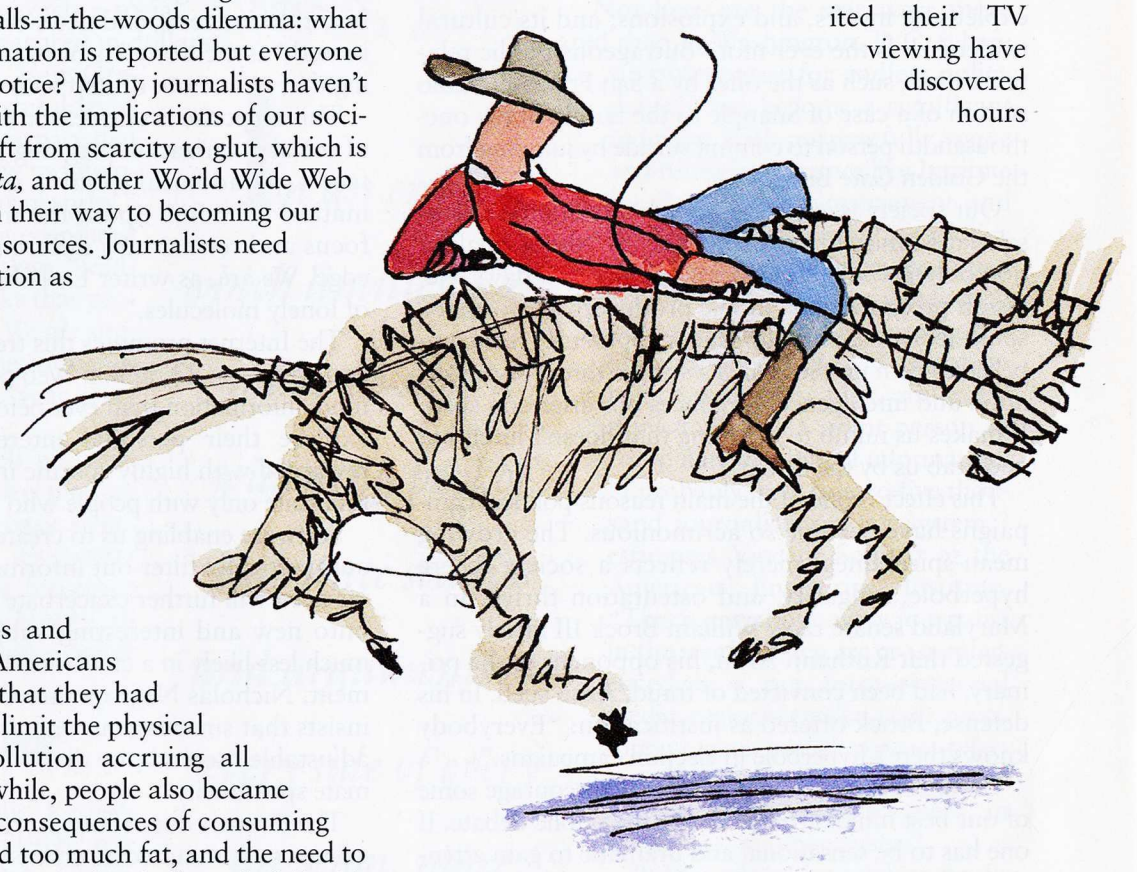
But by limiting their purview to news flashes, journalists are absolving themselves of having to consider a variant of the tree-falls-in-the-woods dilemma: what happens when information is reported but everyone is too distracted to notice? Many journalists haven't yet come to terms with the implications of our society's fundamental shift from scarcity to glut, which is why *Yahoo, Alta Vista,* and other World Wide Web search engines are on their way to becoming our primary information sources. Journalists need to approach information as a natural resource that has to be managed and analyzed more than simply acquired.

A Return to Meaning

In the late 1960s and early 1970s, Americans began to realize that they had to take action to limit the physical smog and other pollution accruing all around them. Meanwhile, people also became aware of the severe consequences of consuming too many calories and too much fat, and the need to limit their intake. Now a similar challenge befalls citizens of the information age. For our individual well-being as well as the health of our democratic society, we must act now to responsibly limit our exposure to information. The goal should be to maintain and even increase access to reliable and useful communication without compromising a certain social serenity. Fortunately, a number of promising remedies for data smog are available if we stop for a moment to look around us.

☛ *Be your own smart agent.* You are responsible for managing your own signal-to-noise ratio, for choosing the information that is accurate, relevant, economical, articulate, and evocative while eliminating anything that blocks out meaning. As your own smart agent, you are also your own data dietitian. Take some time to examine your daily intake and consider whether your info diet needs some fine-tuning—perhaps some data naps in the afternoon, during which you receive no electronic information. Many victims of glut have also found periodic data fasts rejuvenating. One sure way to gauge the value of something, after all, is to go without it for a while.

For example, turn the television off. There is no quicker way to regain control of the pace of your life, the peace of your home, and the content of your thinking. Millions of Americans who have limited their TV viewing have discovered hours of free time with which they can begin to do some of the things they've never found time for. My own approach has been to move the offending item from the kitchen/living room into the closet. There it stays except for a few select hours per week, when I lug it out, plug it in and turn it on. After a brief viewing, it goes straight back to the closet. Since the television has been consigned to the closet, my wife and I play more music, we read more, we talk more.



A suggested trade-off: cancel your cable TV service and apply that same $20 per month to one or more good books. Books are the opposite of television: they

are slow, engaging, inspiring, intellect-arousing, and creativity-spurring.

Another strategy is to avoid news nuggets. All-news channels, wire services, and top-of-the-hour headlines may be the only common fabric we have left, but that isn't reason enough to sacrifice your attention span. Spend those five minutes each hour doing something more productive, like conducting one meaningful conversation.

And recall the playful warning of Michael Dertouzos, head of MIT's Laboratory for Computer Science, in this magazine (see *"Seven Thinkers in Search of an Information Highway," August/September 1994*): "E-mail is an open duct into your central nervous system. It occupies the brain and reduces productivity." Ask people not to indiscriminately forward trivia. "Unsubscribe" to the Internet newsgroups that you're no longer really interested in. Tell advertisers who "spam"—send you unsolicited e-mail messages—that you have no interest in their product and ask them to remove you from their customer list.

☛ *Resist advertising and upgrade mania.* Remember that upgrades are designed primarily as sales tools, not necessarily to give customers what they've been clamoring for.

☛ *Say no to dataveillance.* By writing just a few letters putting your name on do-not-disturb lists, you can greatly reduce the amount of junk mail and unsolicited phone calls that come your way.

☛ *Leave the pager and cell phone behind.* Are wireless communicators instruments of liberation, freeing people to be more mobile with their lives, or more like electronic leashes, keeping people more plugged-in to their work and info-glutted lives than is necessary and healthy? It is thrilling to be in touch with the world at all times, but it's also draining and interfering. For sanity's sake, people ought to be allowed to roam free from the information superhighway for at least some portion of each week.

☛ *Give a hoot, don't info-pollute.* The info glut demands a new kind of social responsibility: an obligation to be more economical about what we say, write, publish, broadcast, and post. Everything from voice-mail messages to office memos to speeches to Web pages should be crisp, clear, and to the point. By reducing the amount of needless information, we will also reduce vulgarity, as people feel less need to be sensational to attract attention. Our tone will become more civil. Our social signal-to-noise ratio will begin to improve. We who have learned not to drink or eat or work to excess will now simply add another virtue to the list.

The payoff for such restraint is high. As we severely limit content, we learn to savor it more. I experienced this paradox firsthand when I asked my brother Jon to film my wedding. He owns a sophisticated Hi-8 camcorder, but he used an old Super 8 instead. In five hours he got through four rolls—12 minutes—of film. Weeks went by while we waited for them to come back from the developer. Finally, we sat down to watch our measly footage. The show was over in a flash, but we were thrilled. The three-minute films are cherished glimpses into our wedding and reception, in marked contrast to an uninterrupted three-hour video that dulls our senses and renders useless our memories. A medium that captures almost everything conveys almost nothing.

☛ *De-nichify.* How to change our electronic Tower of Babel into a modern Agora? The answer is easy, though the solution is not. We need to talk to one another.

By reaching out to different cultures and niches, Brian Lehrer, radio host of WNYC's "On The Line" in New York City, underscores the simple notion that communities work better if people discuss their differences. One highlight is his annual multicultural outreach on Martin Luther King Day, during which he invites listeners to call in and read one-minute excerpts from works about an ethnic group different from their own. On other days Lehrer might conduct informed

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To prohibit firms from deluging us with solicitations based on unauthorized use of personal information, we need a long-sought upgrade of the Federal Privacy Act.

conversations on Bosnia, teachers' unions, and date rape. We can't all have our own radio program, but we can tune in to such shows and read general-interest periodicals; we can make a point to reach across niche boundaries; we can avoid specialized jargon. As we breach cultural divides and pursue interdisciplinary studies, we are engaging in the best kind of education, not simply becoming more efficient at a specialized task but learning how to interface with the rest of humanity.

☛ *Insist that government help defend citizens against data surveillance and data spam.* Taking advantange of the good that technology has to offer without choking on the bad will take strong collective effort. Unfortunately, the cyber-libertarian community has made anti-government rhetoric a fashionable part of the information revolution, mostly in response to thoughtless federal legislation. After President Clinton signed the Communications Decency Act in 1996, which aimed excessively to curb speech online, leading cyber thinker John Perry Barlow issued a "Declaration of the Independence of Cyberspace" that rashly proclaimed the Net to be its own world. But the Net is *not* a new world vested with its own sovereignty; it is a novel and exciting facet of society. Ultimately, the former must fall under the jurisdiction of the latter.

For example, the Telephone Consumer Protection Act of 1991 made it illegal to use an autodialing phone machine or to make calls with a prerecorded voice. This law should be amended to bar software that automatically plucks e-mail addresses and indiscriminately includes them in marketing solicitations. This new legislation should also establish a "do-not-disturb" registry of names, phone numbers, addresses, and e-mail addresses that all mass marketers would be legally obliged to cross-reference.

Indeed, the ability to gather and analyze information conveniently and cheaply means that personal privacy has replaced censorship as our primary civil liberties concern. What once might have been considered harmless personal trivia— which videos you rented this week, whether you like starch in your laundered shirts, whether you buy name-brand or generic aspirin—can today all be turned into useful intelligence by powerful cross-referencing databases. A company called DejaNews Partners, for example, is copying and cataloging, for marketing purposes, every single message posted to each of the thousands of subject-specific Usenet newsgroups.

To prohibit government agencies and companies from using information for unauthorized purposes, we need a long-sought upgrade of the Federal Privacy Act of 1974, which set severe restrictions on the information government could collect on citizens but exempted businesses. Whether you are subscribing to a magazine, buying a modem, signing a petition, renewing your driver's license, taking a random drug test, enrolling your child in school, or paying your taxes, you should be assured that the personal data you turn over will go no further unless you specifically grant permission. This time, the law should exempt no one.

The Federal Trade Commission can also be an important player in limiting data smog. The FTC's current policy is that consumers must match their wits against the claims and resources of advertisers. When it comes to "half truths and motivational manipulations," writes *Advertising Age* columnist Stanley E. Cohen, "the remedy is *caveat emptor*." This hardly seems a fair fight. We need a rejuvinated FTC that criticizes questionable marketing practices and imposes fines.

To ensure that citizens not only have online access to government documents and officials but understand the workings of government, a new Government Information Act must ensure that legislation, regulations, and court rulings as well as tax information is published in formats that any literate person can understand.

Finally, we need to reformulate the issue of information have-nots. The disenfranchised citizens of our country are not in need of faster access to bottomless wells of information but rather better education—high-quality teachers, classroom materials, and buildings. The best way to prevent data smog from settling in is to shift attention and resources toward basic educational infrastructure for all Americans.

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MISSILE DEFENSE: *The Sequel*

SINCE the beginning of warfare, humans have sought defenses against offensive weapons. Not surprisingly, then, the deployment of nuclear-armed missiles by the United States and the Soviet Union early in the Cold War prompted each to begin building missile defenses to protect themselves against these extremely destructive weapons. ★ What is perhaps surprising is that both countries soon recognized that this undertaking would be destabilizing and pointless and agreed in the 1972 Anti-Ballistic Missile (ABM) Treaty not to defend their countries against each other's ballistic missiles. The two superpowers both based their nuclear policies on the notion of deterrence—that maintaining the ability to launch a nuclear counterattack that would inflict massive destruction on the other side was necessary to ensure that the other country would not attack first. ★ Missile defense could

Today's programs for defending against missile attacks are less ambitious than the Reagan-era Star Wars efforts. But the new systems are still too easily foiled, and their deployment would slow arms cuts.

BY LISBETH GRONLUND AND DAVID WRIGHT

ILLUSTRATION BY STEPHAN GUTERMUTH

weaken or even negate the retaliatory capability of the other side, since a retaliatory attack would be small and uncoordinated. Thus, it was believed, their deployment would provoke the other country to take measures to preserve its deterrent. One straightforward but dangerous response to a defensive system would be to build up the size of the offensive arsenal. Another would be to adopt a policy of "launch on warning," which would permit missiles to be launched rapidly when sensors detected an incoming attack. This policy would prevent a country from being disarmed by a first strike but would increase the risk of accidental launch since the decision to launch would need to be made quickly.

Both responses would lead to a more dangerous world, while making the quest for effective defenses futile. It was to avoid this destabilizing dynamic that the United States and the Soviet Union signed the ABM Treaty.

In the mid-1980s, President Reagan, rejecting the logic of the ABM Treaty, launched the Strategic Defense Initiative. Under this program, often referred to as "Star Wars," the Pentagon focused on advanced technologies such as space-based lasers to develop a multi-layered defense of the United States against a large-scale Soviet attack. The nation spent tens of billions of dollars on R&D. The program eventually lost political support, however, because opponents successfully argued that any advances in technology were irrelevant—that Soviet responses would still prevent defenses from being effective—and that building them would diminish, rather than enhance, U.S. security. The logic of the ABM Treaty ultimately prevailed.

But the United States is again moving toward deploying defenses against attacks by ballistic missiles. Iraq's use of conventionally armed Scud missiles against Israel and Saudi Arabia in the 1991 Gulf War raised concern about the proliferation of ballistic missiles, and U.S. efforts shifted away from a system that would shield the entire country from large-scale Soviet attack toward "theater" defenses, designed to protect U.S. troops and allies abroad from shorter-range missiles. But after taking control of Congress in the 1994 election, Republicans put deployment of "national" defenses—this time intended to counter limited missile attacks against U.S. territory—back on the agenda as well.

Proponents of the new missile defense systems argue that the risks to national security of building defenses are lower than in the past, and the benefits higher. Most fundamentally, some argue, the United States and Russia are no longer enemies; Moscow would not be threatened by U.S. missile defenses and thus would not respond in ways that would hurt U.S. security. Other proponents argue that even if U.S. missile defenses did worry Russia, that economically strapped country could not afford an arms buildup in response.

Still other proponents note that today's missile threats are different: their concern is no longer a deliberate large-scale Soviet nuclear attack but rather an accidental or unauthorized launch of missiles by Russia, an attack by China, or possibly threats from Third World countries that acquire long-range missiles. Guarding against these attacks, they argue, would require only limited national defenses that would not threaten Russia's much larger nuclear deterrent. Moreover, this argument continues, U.S. deployment of theater defenses should not concern Russia since these systems would not be intended for use against Russian missiles.

Missile-defense advocates argue that the benefits of deployment are higher than during the Cold War because there is a real and increasing missile threat that it is possible to defend against. They argue that missile-defense systems are far more likely to work against the shorter-range missiles, and against attacks from a small number of long-range missiles, than against a massive assault by sophisticated, long-range missiles—the threat that motivated previous missile-defense programs.

Both political parties have, to varying degrees, bought into the idea that missile defense of some kind is a practical and wise idea; the United States has for the past few years been spending roughly $3 billion a year to study and develop such systems. While this total is down from the peak of some $4.5 billion a year at the height of the Strategic Defense Initiative in the late 1980s, it is far from clear that even this level of effort makes much sense. Thus far, this money has bought only research, development, and testing; building, deploying, and maintaining the systems would require much larger budgets.

Despite the breakup of the Soviet Union, things have not changed quite so much as missile-defense advocates sug-

LISBETH GRONLUND and DAVID WRIGHT are senior staff scientists at the Union of Concerned Scientists in Cambridge, Mass., and research fellows in MIT's Defense and Arms Control Studies Program.

gest. Proponents overstate the missile threat and the ability of defenses to address what threat exists. Perhaps most importantly, they largely ignore the potential security costs of deploying many of the defenses being developed.

Political Battles

The Clinton administration and congressional Republicans have clashed over the timing of deploying a national missile defense system. Last spring, the Defend America Act, introduced in both houses of Congress, mandated deployment by 2003 of a "highly effective" and "affordable" system that would protect all 50 states from "limited, unauthorized, or accidental" attacks. But when the Congressional Budget Office estimated that such a system would cost $31–60 billion to build and an additional $2–4 billion annually to maintain, the House Republicans dropped their legislation out of concern that their party's budget hawks would not vote for it.

The Republicans have written the National Missile Defense Act of 1997 with an eye toward getting a more favorable cost estimate: they have eliminated the requirement that the system be "highly effective," and specify now only that the system be able to deal with very small-scale attacks. Although the requirements remain classified, the system reportedly must now defend against attacks of no more than five to twenty "simple" warheads—that is, warheads that do not incorporate any countermeasures that would help them evade detection and interception.

This experience points to the difficult task that national missile defense advocates face in defining a system that is both politically attractive (it must be seen as necessary and effective) and politically feasible (it must be affordable). The specifics of these defense systems have been left vague precisely because it is difficult to satisfy both requirements simultaneously. Right now no potentially hostile country other than Russia or China has long-range missiles that can hit the United States. Therefore, it has been politically useful to require the system to defend against unauthorized and accidental attacks by Russia or China—these, at least, are threats that exist today. Contrary to common perception, however, "unauthorized" and "accidental" do not necessarily mean "small." Depending on where in the chain of command the control breaks down, such an attack could be quite large. Some argue that the most feasible unauthorized attack would come from a Russian submarine, which carries some 200 nuclear warheads. Yet, defending against an attack of this size requires a much larger and more expensive system than one designed to swat down a few errant missiles.

The Clinton administration holds that there is no immediate threat and that deploying a system before it is needed only guarantees that the technology will be outdated by the time a threat develops. Instead, under its "3 + 3" plan, the administration intends to develop within three years (by 2000) a system that could be deployed in an additional three years (by 2003) if a threat emerges. If in 2000 no such threat is deemed to exist, development will continue. That way, an up-to-date system will always be three years from deployment. President Clinton thus far has prevailed: he vetoed the fiscal 1996 defense authorization bill in large part because the bill's insistence on missile defense would, he said, put the United States "on a collision course with the ABM Treaty." Since this year's missile-defense legislation still mandates deployment by 2003, President Clinton is expected to veto it if it is passed.

Although Clinton has won each battle over deployment of national missile defenses, the Republicans may be winning the war. They have clearly set the terms of the debate, and in trying to undercut their plan for mandated deployment, Clinton's 3+3 plan will move the United States much closer to deployment of national missile defenses than it has ever been.

By remaining vague on the details of its 3+3 plan, the administration has been able to avoid the question of compliance with the ABM Treaty. Although Clinton cited the treaty as justification for his veto of the fiscal 1996 authorization bill, deployment of the 3 + 3 system would almost certainly violate the treaty as well. The bottom line is that the ABM Treaty forbids nationwide defenses, and building a system that covers only part of the United States would be politically unacceptable. Any defense system that complies with the ABM treaty would leave unprotected large parts of both coasts, as well as Alaska and Hawaii.

Providing coverage of the entire United States against even limited attacks would require either that the United States and Russia agree to modify the ABM Treaty or that the United States withdraw from it. The first prospect is unlikely, and the second unjustified. Russia has no incentive to agree to a treaty modification to accommodate U.S. national defenses. Even a limited defensive system would put into place the sensors and other infrastructure needed to allow a relatively rapid expansion to a larger-scale system. And withdrawing from the treaty is permitted only if "extraordinary events" jeopardize U.S. "supreme interests"—a position that is difficult to argue.

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s of both U.S. coasts, as well as Alaska and Hawaii, unprotected.

Opening the Curtains on Theater Defense

Roughly two-thirds of the U.S. missile-defense budget is earmarked for theater rather than national missile defenses. The ABM Treaty allows theater defenses as long as these systems cannot also intercept long-range strategic missiles. The United States is now developing several kinds of theater systems, some that have run into compliance problems with the treaty.

Low-altitude defenses are designed to shoot down short-range missiles—those with ranges up to 600–1000 kilometers, which travel at 2–3 kilometers per second—well within the atmosphere. Such defenses gained fame during the Gulf War when the United States claimed its Patriot system successfully shot down Iraqi Scud missiles—a claim now generally discredited.

Development is continuing on a significantly upgraded version of the Patriot. Other low-altitude defense systems include Navy Area defense, which will be based at sea on Aegis cruisers and destroyers; the Medium Extended Air Defense System, being developed jointly with European allies; and the Arrow program, which Israel is developing with U.S. funding.

These defenses are clearly permitted by the ABM Treaty: they would be unable to intercept 10,000-km range Russian strategic missiles, which reenter at much higher speeds of 7 kilometers per second. Moreover, it would be infeasible to use these systems for national defense because hundreds would be required to cover the entire United States.

The Pentagon is developing other theater defense systems, however, whose treaty compliance is in serious question. These high-altitude systems are designed to defend large areas against missiles with ranges up to 3,500 kilometers and that move at up to 5 kilometers per second, by intercepting them above or in the upper layers of the atmosphere. The United States is developing two such high-altitude systems—the Army's ground-based and air-transportable system known as THAAD, for Theater High Altitude Area Defense, and the Navy Theater Wide system, to be deployed at sea on Aegis ships. The Pentagon plans to buy some 1,200 THAAD interceptors at an estimated cost of $10–15 billion. A prototype system would be deployed around the turn of the century, with full-scale deployment beginning in 2004. A few years later, the Navy Theater Wide system would be deployed, with 650 interceptors on 20 or more ships.

Neither system has done well in tests, however, so these schedules may be optimistic. As of March, THAAD had failed all four of its intercept tests, leading Pentagon officials to suggest a major restructuring of the program. Navy Theater Wide is not as far along in its test series, but as of early this year the system had failed both of its intercept tests.

Some proponents incorrectly argue that the two high-altitude theater defenses could not be used as part of a national defense. Although not designed to protect U.S. territory, these high-altitude defenses are designed to be mobile and could readily be moved to the United States in a time of crisis. Because these systems intercept outside or high in the atmosphere, where the missile will not be maneuvering, the defense system can accurately predict the trajectory the missile will follow. Thus if these defenses perform as intended against missiles with speeds of 5 kilometers per second, then they would also be capable of intercepting strategic-range missiles traveling at 7 kilometers per second.

Moreover, if advanced sensors now under development are used, the ground area covered by these systems could be large enough to permit a nationwide defense. These sensors would provide early detection of missile attack, allowing interceptors to be launched sooner. The U.S. early-warning radars, to be upgraded as part of the national missile defense program, could allow 6 or 7 Navy Theater Wide batteries to cover the entire United States; indeed, this is the basis for a limited national defense proposed by the Heritage Foundation and others. Even better sensor data would be available if the United States deploys the Space and Missile Tracking System currently being developed for use by both national and theater defenses. This program, formerly known as "Brilliant Eyes," would use about two dozen satellites in low earth orbit. The Clinton administration wants deployment by 2006, but Congress is pushing for 2003. If such a network of space-based sensors were deployed, as few as ten THAAD or three to four Navy Theater Wide batteries could cover the United States, providing, in effect, a national defense—precisely what the ABM Treaty bans.

Indeed, early in THAAD's development, a Pentagon study concluded that the system would violate the Treaty. The Clinton administration therefore began negotiating with Russia in November 1993 to modify the treaty to permit testing and deployment of both THAAD and Navy Theater Wide. Russia balked at the proposed changes, however, and the negotiations were deadlocked until very recently. In response to this lack of progress, the United States stated that it nonetheless intended to proceed with both THAAD and Navy Theater Wide, claiming that both would be treaty-compliant. During the March summit with President Clinton, President Yeltsin apparently dropped essentially all of Russia's negotiating positions, including restrictions on space-based sensors. This agreement, if it stands, would thus permit deployment of defenses with significant strategic capabilities, weakening the treaty.

Assessing the Benefits of Defense

Making rational decisions on U.S. missile-defense policy requires weighing the potential security benefits and costs for both national and theater missile defenses. The benefits will depend on both the need for such systems and their likely effectiveness.

Proponents are seeking national missile defenses to protect U.S. territory against three possible threats: accidental or unauthorized

launches of long-range Russian or Chinese missiles; deliberate attacks from China; and potential future attacks from other, hostile countries.

The possibility of an unauthorized or accidental launch of nuclear missiles is real. But missile defenses are not the best safeguard. In fact, deployment of national missile defenses could *increase* this threat, if it prompted Russia or China to rely more on launch-on-warning strategies or increase their alert rates. Other, cooperative measures would be more effective and less expensive. The nuclear powers could, for example, agree to install mechanisms to destroy errant missiles after launch, or to store warheads separately from missiles.

This approach has an added benefit: depending on where in the chain of command an accidental or unauthorized launch occurs, such an attack could be so large as to overwhelm a limited defense. Destroy-after-launch mechanisms would be able to address any size launch, and removal of warheads from missiles would preclude such a launch in the first place. If the United States is interested in resolving this concern, then working with Russia and China would be the best approach since it is clearly in their interests to prevent such launches, too.

The threat of a deliberate Chinese attack is very small, given the certainty of U.S. retaliation. Moreover, to retain its deterrent against the United States, China would take steps to prevent U.S. national defenses from being effective against its missiles.

The "rogue nation" threat has been exaggerated. Other than Russia and China, no country considered hostile to the United States has missiles capable of coming even close to U.S. territory.

There are five countries with missiles that are typically considered threats to U.S. interests: Iran, Iraq, Libya, North Korea, and Syria. Iraq, however, is not a realistic threat: its missile program is being dismantled under the terms of the UN resolution that ended the Gulf War, and long-term monitoring is being set up to ensure that Iraq will not be able to resume this program. All missiles deployed by the other four countries are either 300-kilometer-range Scud missiles acquired from the Soviet Union or derivatives of these missiles with ranges up to about 600 kilometers—well short of the 5,000-10,000 kilometers any of these countries would need to strike the United States.

Of the four remaining countries, North Korea has the greatest indigenous ability to develop longer-range missiles. However, despite reportedly working on a 1,000 kilometer-range missile—the "Nodong"—since the late 1980s, North Korea has yet to test a missile of this range. Foreign technical assistance could, of course, speed the development of longer-range systems in North Korea or elsewhere.

National missile defenses could raise, rather than lower, the threat of an unauthorized or accidental attack if they prompted Russia and China to respond by putting their nukes on hair-trigger alert.

But even with help, developing long-range missiles is a demanding and expensive process. And U.S. satellites would be able to observe missile flight tests, providing clear warning of threatening developments.

The other possible route for a developing country to obtain long-range missiles—acquiring them from one of the few countries that already has them—is highly unlikely. Long-range missiles are typically about 20 meters long and weigh many tens of tons, and are therefore essentially impossible to steal without the knowledge of the authorities. And it would be against Russia's and China's self interests to sell long-range missiles, because such sales would prompt severe economic sanctions under an international agreement prohibiting such transfers and because these missiles could

be turned against them.

Moreover, even if a developing country did seek to attack the United States with weapons of mass destruction, long-range missiles are probably the least likely method it would choose. U.S. satellites would pinpoint the origin of any missile attack, so the threat of quick retaliation will be a powerful deterrent. Meanwhile, other methods of delivery, such as those used in the World Trade Center and Oklahoma City bombings and in the Tokyo subway gas attack, are relatively cheap, require only low technology, can be used clandestinely, and can be accurately targeted to make the most of a limited arsenal.

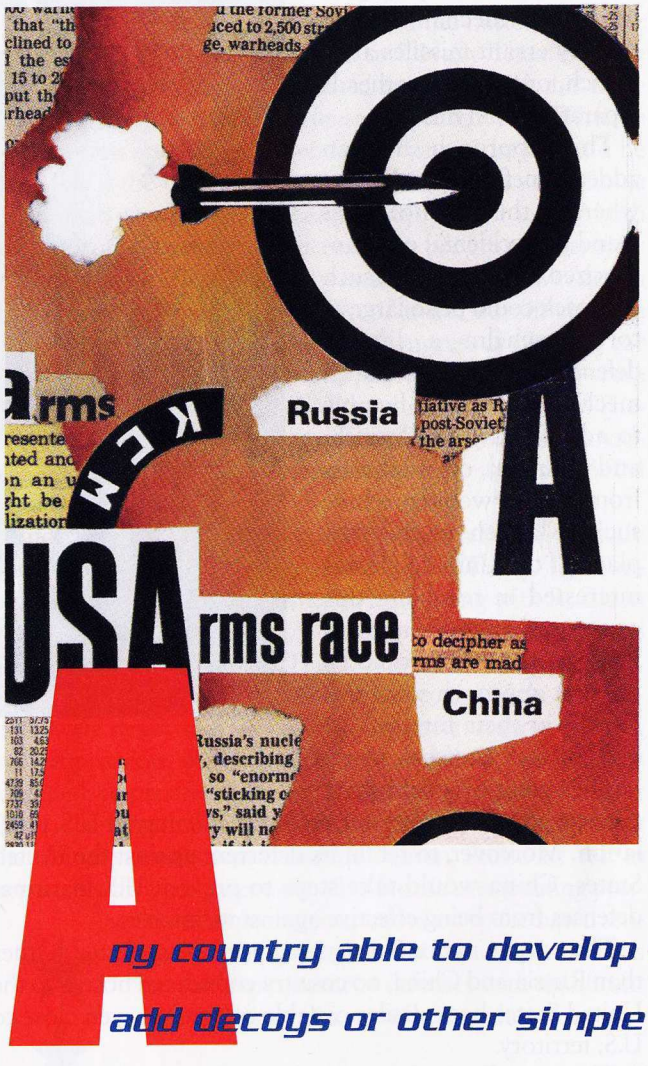
Leaving aside the question of the future threat, how effective might limited national missile defenses be if a threat did emerge?

The assumption that underlies current plans for national defenses—that incoming missiles would use no countermeasures— is unjustified. Any country that could develop a long-range missile could also deploy a variety of simple countermeasures that would make the job of the defense much more difficult if not impossible. Any missile delivering chemical or biological weapons can simply overwhelm the defense by using a large number of small warheads, called submunitions. A nuclear-armed missile can take advantage of the fact that interceptors for national missile defense systems are designed to work at high altitudes where, because of the thin atmosphere, objects of different shapes and mass travel at the same speed. This makes it possible to use lightweight decoys that simulate the warhead to create a large number of false targets or to hide the warhead in a large balloon so the interceptor would not know where to aim. Despite decades of work, the United States has not found a solution to the problem of such countermeasures.

Other ways to address the possible proliferation of long-range missiles are likely to be more effective and cheaper than missile defenses. Because U.S. satellites would provide warning of long-range missile development and deployment, the United States could destroy such missiles preemptively. More important, the United States has options available that could prevent a threat from materializing in the first place. Some diplomats believe, for example, that North Korea may be willing to bargain away its entire missile program in exchange for economic assistance, much as it did with its nuclear program.

The analysis for theater missile defenses is different. The short-range missiles possessed by Iran, Libya, North Korea, and Syria do represent a possible threat to U.S. troops or allies abroad. These missiles are armed with conventional warheads and possibly, in some cases, chemical or biological weapons. However, the 1,000-kilometer range Nodong missile reportedly under development by North Korea is essentially the longest range missile achievable using Scud technology; any theater missiles the United States will face in at least the medium-term future will have shorter reach. High-altitude defenses are not needed against this threat; low-altitude theater missile defenses are appropriate for this purpose.

Missile-defense proponents claim that short-range missiles will be relatively easy to defend against, but this may not be so. As with national defenses, the effectiveness of theater defenses will depend heavily on the countermeasures that the attacker uses. For example, the Patriot succeeded in all 17 of its intercept tests prior to the Gulf War, yet apparently shot down at most one, and probably zero, Iraqi missiles. The Scuds broke into several pieces as they reentered the atmosphere, inadvertently creating decoys and causing



the warhead to tumble in unpredictable ways.

Incorporating countermeasures into any new theater missiles produced would be easier than building the missile itself, and retrofitting old missiles with simple and effective countermeasures would not be difficult. Both low- and high-altitude theater defenses would be defeated by submunitions. High-altitude defenses would also be susceptible to the

same types of simple countermeasures as the national missile defense systems, thus shrinking the area covered by the defense. As a result, high-altitude defenses would provide little, if any, defensive capabilities beyond those provided by low-altitude defenses.

How Defenses Lower Security

Even though the United States and Russia are scaling back their nuclear forces, the two countries still base their military relationship on nuclear deterrence. Both countries still rely primarily on nuclear-armed ballistic missiles to provide this deterrence. Moreover, there is no evidence that either country plans to move away from nuclear deterrence, despite growing pressure from the world's non-nuclear nations for a commitment to nuclear disarmament. Russia is equally wedded to nuclear deterrence and views nuclear weapons as key to its superpower status and as a counterweight to its deteriorating conventional military strength.

This continued commitment to deterrence means that to whatever extent defenses threaten or appear to threaten deterrent forces, the same old problems will arise. Russia and China see as a fundamental security issue the need to preserve their ability to inflict a punishing nuclear retaliatory blow. It is therefore unlikely that these countries would sit idly by while the United States deployed a defense that they believed might render a retaliatory strike ineffective.

Russia would probably endow its missiles with countermeasures to protect them against U.S. missile defenses. A reliance on countermeasures, however, will introduce new uncertainties in Russian military planning. Russian leaders may find it implausible that the United States would be spending tens of billions of dollars on defenses that would be so easy to defeat. Thus, even if scientists and engineers are confident that their countermeasures would work, it is not clear they would be able to prevent Russia's military and political leaders from responding in other, destabilizing ways as well.

While it can ill afford an arms buildup in response to U.S. missile defenses, Russia has other, less costly, options that could be equally problematic. Russia could, for example, increase its reliance on a policy of launch-on-warning or increase its alert rate, raising the chance of accidental and unauthorized launches. Moreover, Russia could simply refuse to cut its nuclear arsenal further. When Russia ratified the first Strategic Arms Reduction Treaty (START I), which cuts deployed forces to some 8,000 warheads, it made its fulfillment of the agreement contingent on continued U.S. compliance with the ABM Treaty. The START II agreement, which would cut deployed forces to 3,500 warheads, was ratified by the U.S. Senate but has run into deep political problems in the Duma (parliament) in part because of U.S. plans for missile defense. If Russia does ratify START II, the Duma will certainly link fulfillment of the treaty to preservation of the ABM Treaty.

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Even if Russia were not concerned about U.S. missile defenses at START II or III force levels, defenses would almost certainly be a significant barrier to much deeper cuts in Russian (and hence U.S.) nuclear forces. As arsenals shrink, deterrent forces will become more vulnerable to even limited defensive deployments. Thus, those who argue that a limited U.S. national missile defense would entail no security costs since it would not threaten Russia's large arsenal ignore the fact that U.S. security is best served by irreversible cuts in nuclear weapons to very low numbers—tens or perhaps 100. (Of course, some policymakers want to retain a large U.S. nuclear arsenal indefinitely and are thus unconcerned that missile defenses could preclude deep cuts.)

Even if Russia has finally agreed to a treaty modification permitting high-altitude defenses, deployment of such defenses could still stand in the way of deep cuts. That Russia has serious concerns about the strategic capability of these defenses is clear from the past three years of negotiations, and these concerns have presumably not evaporated despite Yeltsin's concessions. Indeed, Russian agreement may only signify that it is comfortable with such defenses at START III force levels, and that it does not intend to cut significantly further.

The prospect of missile defenses might also cause Russia to keep open the option of expanding its arsenal in the future by refusing to agree on controls on the fissile material that nuclear weapons are made of. Russia might be reluctant to declare surplus much of its large existing stocks, for example. That would run counter to U.S. efforts to render its surplus fissile material difficult to re-use or steal, and its attempts to convince Russia to do the same.

Considering China

U.S. security interests also dictate that the United States consider Chinese reactions to its missile defense plans. Although not a party to the ABM Treaty, China bases its nuclear planning in part on the treaty and has historically been concerned about U.S. and Soviet missile defense programs. China is believed to have several hundred nuclear weapons but perhaps only about two dozen are able to reach the United States. Even a limited national missile defense system, therefore, could undermine or negate the Chinese deterrent.

China has expressed concern about high-altitude theater defenses too. Sha Zukang, China's ambassador to the Conference on Disarmament, noted in a statement to the U.N. General Assembly last October that such systems will "pos-

sess the capability to intercept strategic missiles" and that their development thus would dampen China's "enthusiasm to participate in the global process of arms control and disarmament." Moreover, U.S. deployment of high-altitude theater defenses would open the door for Russia to do the same. Such a move could threaten the bulk of China's missile force, which have ranges of less than 3,500 kilometers and constitute the backbone of its deterrent against Russia.

China also worries about possible transfers of U.S. theater defenses to neighboring countries and U.S. deployment of sea-based systems in the region. The United States has tried to enlist Japan as a partner to help fund development of THAAD. China views Japan as a latent nuclear power, and given the historical enmity between the two countries, is uncomfortable with the prospect of a potential combination of Japanese nuclear weapons and missile defenses. Japan has recently all but opted out of the THAAD project, however, partly because the cost is too high and partly to minimize tensions with China.

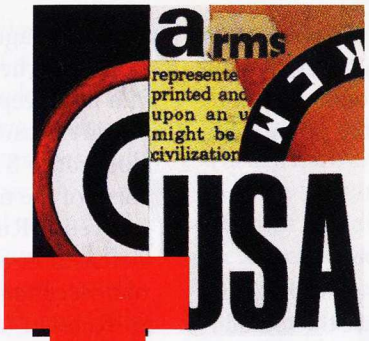
China is also upset by U.S. plans to sell Patriot defenses to Taiwan in response to the intimidating missile tests China conducted off Taiwan's coast prior to Taiwan's elections last year. Because these are only low-altitude defenses, however, such a sale is unlikely to affect China's nuclear or arms-control policies.

Given its concerns, China could react to U.S. missile defenses in a number of ways that could reduce U.S. security and hinder further efforts to control and eliminate the world's nuclear arsenals. To preserve its nuclear deterrent, China, like Russia, could build up its nuclear forces or adopt a launch-on-warning posture. China could also decide to keep open the option of building up by refusing constraints on fissile material production. The United States is seeking an international treaty prohibiting further production of fissile material for nuclear weapons, partly as a way to place some controls on the nuclear-weapon programs of the undeclared nuclear states—India, Israel, and Pakistan. China's agreement to this treaty is essential, both because of its own nuclear arsenal and because its participation will be needed to gain that of India and, in turn, Pakistan.

If and when the United States and Russia continue to cut their deployed nuclear weapons to roughly the numbers held by the smaller nuclear powers—China, Britain, and France—it will become necessary to include these countries in negotiating deeper cuts. But in response to U.S. defenses, China could hamstring this process by refusing to accept limits on its deployed arsenal.

Finally, because both Russia and China are potential suppliers of nuclear and missile technologies to other countries, their participation in international nonproliferation efforts is crucial. But the ill will that missile defense deployments could cause may make both Russia and China less willing to cooperate with the West on restricting transfers of sensitive technology to other countries, or to participate in other nonproliferation initiatives.

Thus the overall result of U.S. deployment of national missile defenses and high-altitude theater defenses could well be that nuclear reductions and other irreversibility measures grind to a halt and that the United States and Russia become locked in at high levels of deployed weapons, while retaining their ability to rapidly build more. The other nuclear weapon states would then refuse to become involved in nuclear arms reductions. Creating such barriers to deep nuclear reductions and disarmament, which the nuclear weapon states are obligated to pursue under the Nuclear Non-Proliferation Treaty (NPT), would become increasingly unacceptable to the 180 non-nuclear-weapon state members of the NPT. Over time, this discontent could weaken the international nonproliferation regime.



There is no missile threat from developing countries that justifies national missile defenses, and there may never be.

These potential costs to U.S. security might be worth risking if the missile threat were greater and defenses were a more effective means of countering this threat. But this is not the case. There is no missile threat from developing countries that justifies national missile defenses, and there may never be. There are more effective means of addressing the problem of accidental and unauthorized launches from Russia and China. No long-range theater missiles justify deployment of high-altitude theater defenses; low-altitude defenses will provide most if not all of the realizable benefits of defenses against existing and likely future theater missiles, and without the attendant security costs.

The desire to defend the United States, its troops, and allies against all threats is understandable. But U.S. policymakers must weigh both the costs and benefits of deploying missile defenses. U.S. security—and indeed international security—will best be served if the United States forgoes national missile defenses and high-altitude theater defenses. ■

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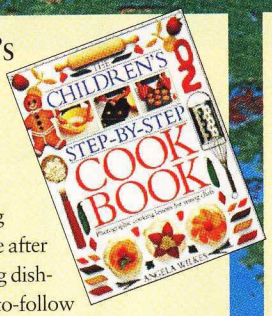

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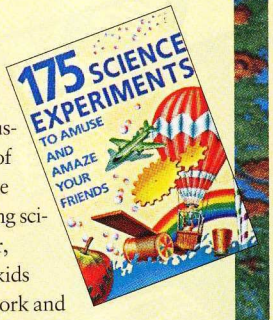

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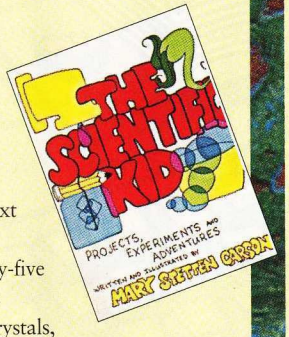

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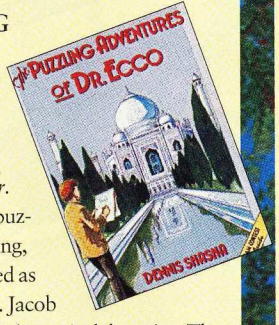

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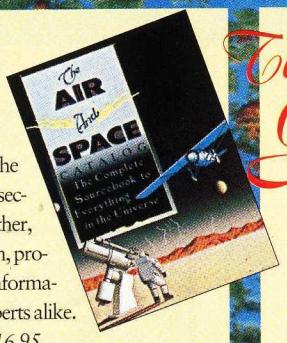

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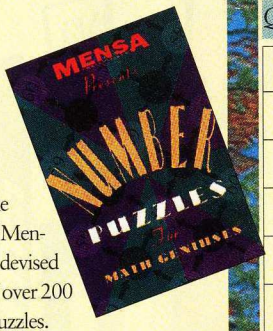

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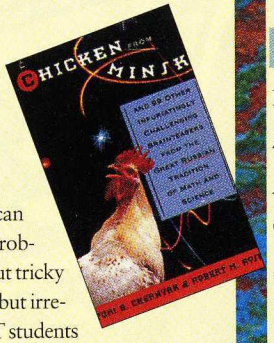

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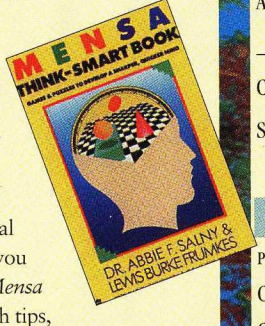

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CLICKING ONTO Webzines

IT couldn't last. Ever since bursting into popular consciousness in the early 1990s, the World Wide Web kept growing chaotically. Universities had Web sites. Companies had Web sites. Individual families had Web sites. Any organization that didn't have a Web page seemed to be labeling itself a relic. But after the initial flurry of clicking around, most visitors to the Web wanted something to sink their teeth into. After awhile, grainy pictures of half-full coffeepots in England just didn't cut it anymore. Oh, sure, if you poked around enough you could find a brilliant essay or collection of digitized art or clever interactive game. But it was every surfer for him or herself. Although a breed of Net users reveled in this chaos and unpredictability, many people who logged on found the Internet about as fulfilling as wading through a warehouse full of pages ripped from student notebooks.

COLLECTING, SELECTING, AND REFINING THE STORIES THAT GO ONLINE, WEB-BASED MAGAZINES ARE TRANSFORMING THE INTERNET EXPERIENCE. BUT THESE EMBRYONIC PUBLICATIONS DON'T YET FULLY EXPLOIT THE NEW MEDIUM'S POTENTIAL—AND THEIR FINANCIAL VIABILITY IS IN QUESTION.

It is amid this mess that Web magazines have risen to popularity in the past year. A visit to *Salon*—a webzine of reviews and essays founded by expatriates from the *San Francisco Examiner's* arts section—guarantees a few snappy essays on life, culture, and politics in the '90s by name-brand writers. Enter the electronic portals of Microsoft-owned *Slate* and you can eavesdrop on a high-minded debate

BY HERB BRODY

among policy wonks about the political and economic issues du jour. Tap into *HotWired* for spicy and often abrasive commentary about the medium itself.

In editorial direction, webzines buck the trend in print publications, where success has recently accrued mainly to specialty titles, especially those that give advice on how to live and what to buy. Advertising dollars flow into these publications, attracted by readerships presumed to be in a buying or self-improving frame of mind. Two of the wealthiest people in America—Patrick McGovern and William Ziff—made their fortunes peddling computer magazines. The new breed of webzines, by contrast, appeals to readers less with buying advice than by projecting an attitude. They do this in the form not of practical articles of the sort that fill the bulging pages of computer and "lifestyle" magazines but with compendiums of commentary—essays, cultural critiques, political analysis.

The strength of webzines as a new medium will depend on how well they take advantage of the interactive features that are uniquely possible online.

A magazine on the Internet can do much that its printed cousin cannot. Articles can include links that readers click on to find additional information. Previously published stories can be read as easily as this week's issue. Webzines can enrich their stories with sounds and video. Web publications can create structured online forums where readers can debate among themselves—and with the magazine's writers and editors—the ideas presented in the magazine's articles. Material online can be updated as needed, incorporating new information and correcting errors.

Overall, the dozens of webzines differ from each other as drastically as the array of titles on a conventional newsstand, ranging from the sassy countercultural rant-rags such as *Suck* (which devotes much of its space to bashing other webzines) to the sober and establishmentarian *Intellectual-Capital* to the New York artsiness of *Word*. The quality can be quasi-*New Yorker* literary or just-past-amateur. Designs also vary greatly, from gray *Slate* to the self-conscious hipness of *HotWired*, with its gonzo icons and pages saturated in the neopsychedelic, Day-Glo colors that its print sister, *Wired*, inflicts on its readers. But a look at the top tier of webzines—including *Slate*, *Salon*, and *HotWired*—reveals most of what these publications are doing well, poorly, or not at all.

Follow That Link

A typical webzine invites the visitor not so much to study its text but to hop around within it, clicking on icons and highlighted phrases to see where they lead. In this exercise, the act of reading is submerged beneath the drive to explore. Pages are riddled with convenient electronic tunnels. The experience is less like reading a magazine than strolling through a bookstore or library, where you will expect to look at a lot of titles but may come out having actually read little.

A computer screen is not the best way to do extended reading. Thus it's not surprising that webzines favor short pieces. Print magazine feature articles (like this one) typically run 4,000 words or more. In *Slate*, *Salon*, and other webzines, a typical article is 1,000–1,500 words. These pieces may whet the intellectual appetite or stir up ideological fervor among those already in agreement with a writer. But because staffs are small and budgets low, and because the Web puts a premium on rapid production of new material, the stories generally lack the thorough reportage that makes for the most fulfilling reading experience—and that changes people's minds.

The strength of webzines as a new medium, then, depends on how well they take advantage of the interactive features that are uniquely possible online. Many webzines are still groping for how best to use the new technologies. Most of these publications amount to words on a screen—a vertical, glowing rendition of the magazines people have been reading for decades. Despite their multimedia cachet, webzines typically contain a smaller concentration of photographs, illustrations, and charts than one would find in a printed publication.

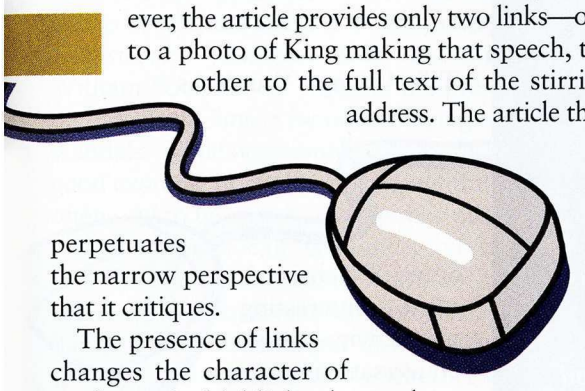
What webzines do provide are links to related information. The quality of these links varies widely. *Slate* takes particular care in its compilation of links. A recent article about how ballot initiatives in Arizona and California regarding the medical use of marijuana could affect the war on drugs, for example, links to the text of the referendums and to documents from organizations arguing pro and con. It is one-stop shopping for political information.

A well-compiled set of links can make a webzine worth visiting. By January, the Oakland school board's controversial decision to formally recognize black English as a distinct language—Ebonics—had been pretty well hashed over in the media. But accompanying *Slate*'s article on the topic were links to a detailed synopsis of the decision put out by the Oakland Unified School District. Here the reader could find out without the filtering of reporters and commentators exactly what course of action the school board was recommending—a particularly helpful service in this case, given widespread confusion about the school board's intent. For historical context, the reader could hop to a 1972 article by University of Pennsylvania linguist William Labov that provides scholarly underpinning to the Oakland decision.

HERB BRODY is a senior editor of Technology Review.

Links can also give readers a handy "reality check" that pressures writers and editors to get their facts straight. Dan Kennedy, a media critic for the printed *Boston Phoenix* and for *Salon*, explains: "I like to think I'm a careful reporter when I'm writing for print, but in *Salon* I really have to get it right."

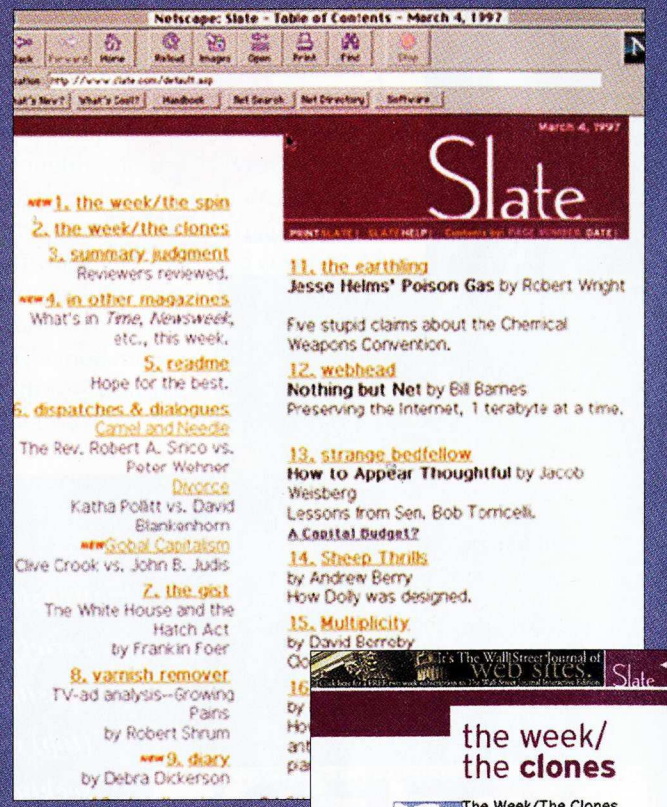
But many webzine links seem thrown in with little thought and even work against a story's theme. A *Salon* essay convincingly decries the reduction of Martin Luther King, Jr., to a "safe" icon of both the right and the left. The writer worries that for many people, King has become just a reason for a holiday and an "I Have a Dream" sound bite. Oddly, however, the article provides only two links—one to a photo of King making that speech, the other to the full text of the stirring address. The article thus perpetuates the narrow perspective that it critiques.



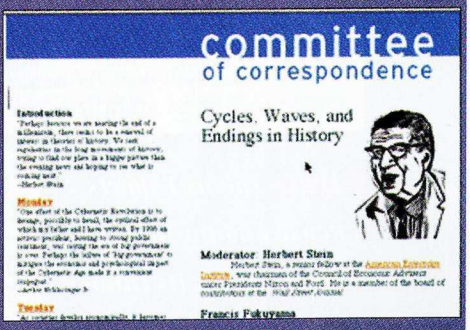
The presence of links changes the character of reading. A highlighted word tempts the reader to click—where will it lead? The webzine page becomes a platform from which to dive into the roiling waters of the Internet. Each link is like a little exit door, and if the pastures are richer on the other side, online grazers will be lost. For this reason *Slate* and some other webzines gather up their links and put them at the end of articles rather than permitting them to interrupt the flow of reading.

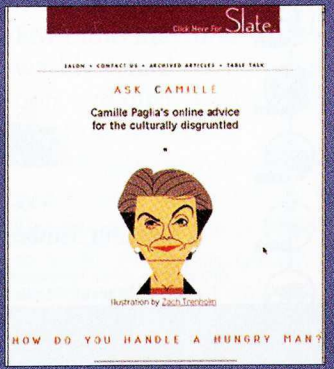
Editors of any publication strive for quality control. Links represent a kind of surrender on this front. Not only is the linked-to site beyond an editor's control, but so are the sites that *it* links to, and that each of those sites links to, and so on throughout the Net. With each hyperstep away from the webzine's site, the possibility multiplies that a reader will encounter unchecked or unsavory pages (or pages that have disappeared). One *Slate* story about body piercing, for example, provided a link to a site that prominently featured links of its own—to pornographic pages. Such missteps are probably unavoidable in a medium as big and uncontrolled as the Internet.

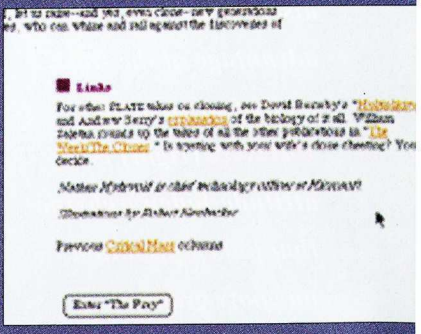
Bad links are worse than no links at all, if only for the deflating feeling of expectations dashed. A provocative essay in the webzine *Suck*, for example, pointed out that with operations like *Wired* magazine and America Online hitting bad patches and laying people off, the defiant "geek culture" that had been contemptuously thumbing its nose at management was finding itself having to be more

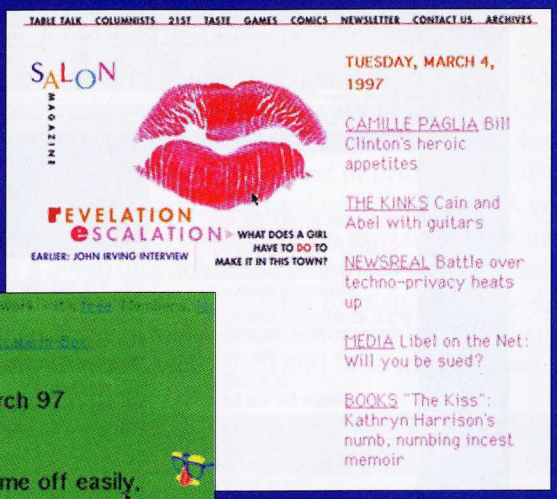


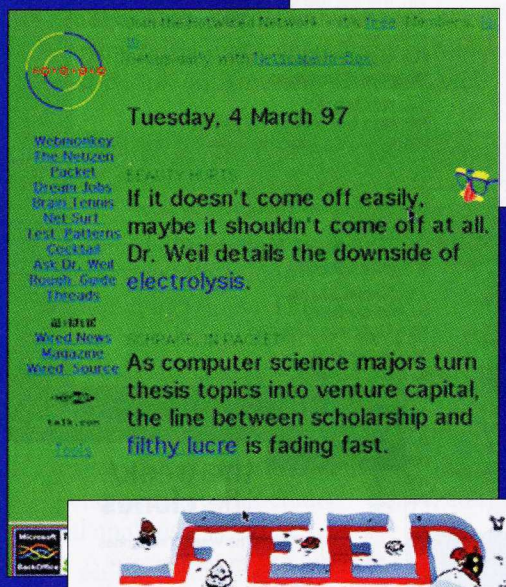
SLATE, *published by Microsoft, offers commentary and debate on political, ecomomic, and cultural issues. The webzine is notable for its Committee of Correspondence—a moderated forum of experts who debate an assigned topic online over the course of a week.*



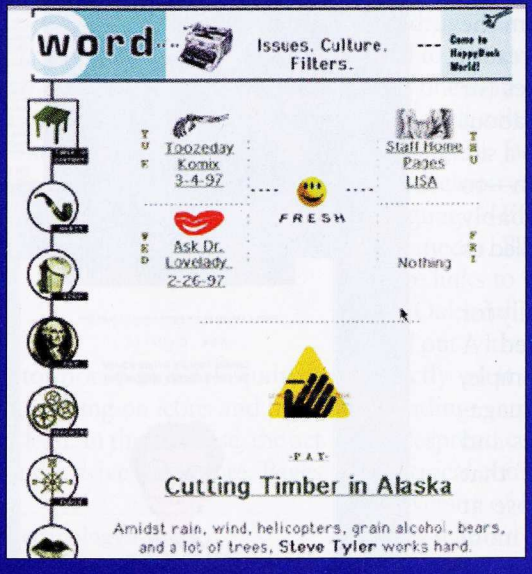








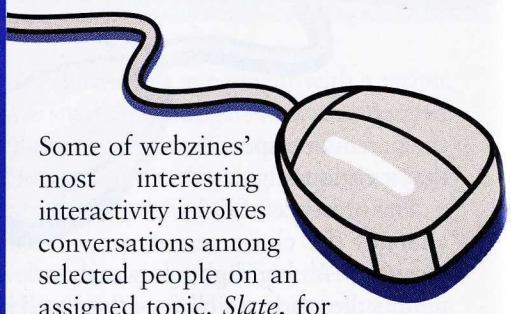
Webzines exhibit a variety of styles and missions.* SALON *(top) caters to readers seeking mainstream reviews of the arts and literature, and offers a clean look and feel.* HOTWIRED *(left, above) provides spicy and often abrasive commentary on digital culture.



FEED* *(above) sports a dense and uninviting contents page; its innovations include panel discussions that take advantage of the Web's nonlinear structure.* WORD *(right) is an attitude-laden webzine that puts a premium on goofy graphics.

circumspect; having even a bad job was at least a job. It is not hard to find "dozens of people swapping enthusiasm for misery," said *Suck*—and highlighted this last sentence to indicate it was a hyperlink. But the link led to a newsgroup called alt.angst—an online bellyaching extravaganza filled with diatribes about atheists, Bill Gates, and many other pet peeves. A search through hundreds of recent postings found none discussing job anxiety.

Talk Amongst Yourselves



Some of webzines' most interesting interactivity involves conversations among selected people on an assigned topic. *Slate*, for example, features a "Committee of Correspondence"—a panel of four or five people who post every day for a week on a given subject. Messages often respond to points made in the previous day's submissions by the other panelists. The Committee of Correspondence operates under the gentle nudging of economist Herbert Stein, who frames the question on the first day, and then weighs in on every subsequent day to summarize what the other participants have been saying and to ask new questions.

The power of *Slate*'s panels lies in the credibility of the participants. The webzine has managed to assemble groups of thinkers who know what they're talking about and write well (or are the beneficiaries of fine editing by the *Slate* crew), and who refrain from turning political issues into personal attacks. For an Internet discussion, that's a rare triple whammy. A panel arguing the merits of a balanced-budget amendment, for example, included Jim Miller of George Mason University, director of the Office of Management and Budget from 1985 to 1988; Robert D. Reis-

chauer of the Brookings Institute, director of the Congressional Budget Office from 1989 until 1995; Robert Shapiro of the Progressive Policy Institute, an economics adviser to the Clinton administration; and Sen. Paul Simon (D-Ill.). *Slate*'s contribution was not in giving these analysts a spotlight—they are for the most part the same talking heads that appear on Sunday TV political shows—but in constructing a forum where they can respond to one another's arguments and move beyond the glib answers that television often fosters.

In another *Slate* feature, two people engage in a long-term correspondence with each other on a provocative subject. The "Dialogs" column has grappled with whether there is a God and whether divorce should be more difficult to obtain, and featured a highly charged debate between *Newsweek's* Jonathan Alter and the *New Republic's* William Powers over whether the press is going too easy on President Clinton by underplaying the administration's scandals. While occasionally sparks fly, these debates are a good example of the kind of thoughtful and civil exchange often said to be missing from public discourse.

Even experts can become a bit cranky, of course. *HotWired*'s "Brain Tennis" feature—a week-long debate between two people on a technological issue—veers toward flaming, with flavorful put-downs such as this one from a spirited conversation about whether nanotechnology is more hype than substance: "To call this concoction a straw man is an insult to straw."

A webzine page peppered with links is not so much a document to read as a platform from which to dive into the roiling waters of the Internet.

Feed, more than other Webzines, constructs its panel discussions in the spirit of the Web's nonlinear structure. A selected group of people post short essays on a given topic. But reading through the forum you come across hyperlinks embedded in the text. Clicking here takes you to a response by one of the other panelists to the particular point being made in that specific sentence or paragraph. And within that response are other responses. Reading a Feed debate is like stepping into a hall of mirrors—the discussion swirls endlessly around in a manner that would be impossible to duplicate in print. *Slate* has started to use a similar style in its Committee of Correspondence.

Webzines also offer readers the opportunity to converse with one another online. Authors and editors occasionally wade in to join the stream of commentary and response. Democratic strategist and former Clinton campaign adviser James Carville, who writes a column of political commentary in *Salon* called "Swamp Fever," has posted frequently. So has novelist Anne Rice, who has published a series of diary entries in *Salon*. This kind of give-and-take occurs in print as well, of course, such as when a magazine appends an editor's or writer's response to a published letter from a reader. In webzines, however, the commentary can take on a life of its own and, without the delays of printing and mailing, the conversation assumes a more bantering, informal quality.

Print publications try to select and edit letters columns to roughly the same level of erudition and sophistication as the articles on which they comment. In webzines, however, this is not the case; reader forums are distinctly lower in intellectual power and cogency. Many contributors to these forums are curt, defensive, off-the-point, and have a tendency to substitute passion for intellect and knowledge. The moderator of *Salon*'s "Table Talk" spends much of her efforts "dousing waters on flame wars," admits David Talbott, *Salon*'s founder and editor.

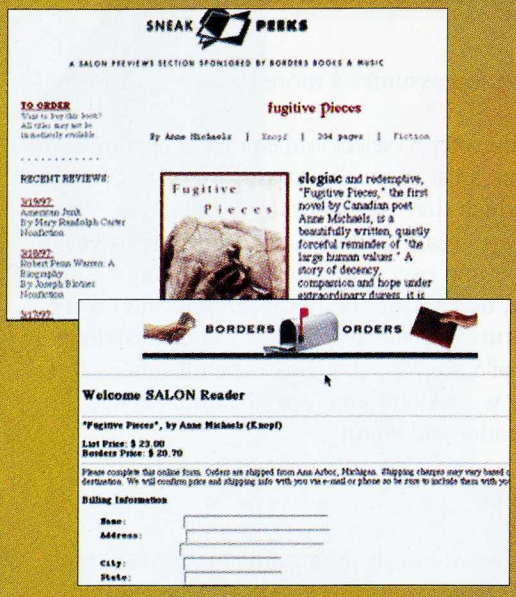
Pictures and Sound

Some webzines are cautiously taking advantage of the Internet's multimedia capability. A *HotWired* article about Jimmy Carter, for example, provided a link to a 20-minute audio of a conversation with the former president, in which he expounded in his gentle Georgia drawl on his philosophical and religious views at far greater length than appropriate to quote in the article. To hear the interview requires RealAudio software, which its creator, Progressive Networks, offers free over the Web.

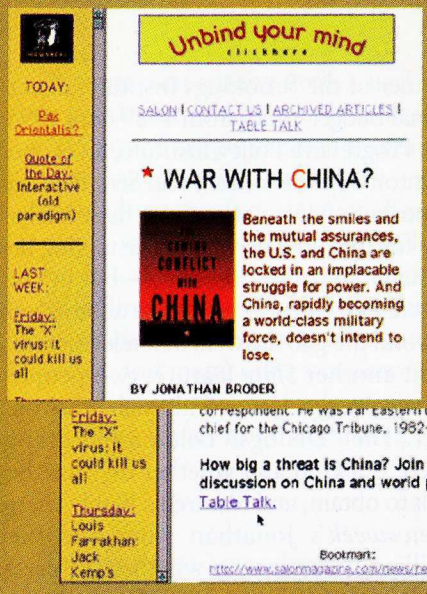
The interview is one of a series that *HotWired*'s "Netizen" section has run. In others, civil rights leader and ambassador Andrew Young has talked about affirmative action and Chinese human-rights activist Harry Wu has spoken of his experiences in a Chinese labor camp. Listening to Wu's tense voice and elegant statement, for example, one senses his pain and his passionate ideals for a better future in a way that a transcript of the interview could not convey.

Unlike listening to an interview on radio or watching it on television, the Web's audio capabilities allow the user to pause the playback, back up, or skip forward. Oddly, given that such interview tapes are essentially "free" content whenever a webzine covers a story, neither *Slate* nor *Salon* offers such audio features. Their hesitation stems partly from the low quality of sound. Ears accustomed to CDs and FM radio may find Web audio a step back in time. The warbly sound resembles, at best, a strong AM radio station, and often is more akin to that of a shortwave broadcast from overseas.

Webzines use video sparingly. *Slate*, for example, accompanies each movie review with a brief clip from the film. Unfortunately, technical quality is poor. The webzines have to trade off picture quality against transmission time, and choose speed. Not only are the images low resolution, but



Because Borders sponsors **SALON'S** *book review page (left), each review includes a form for ordering the volume from the bookstore chain. Like other webzines, Salon solicits comments from readers (right); its Table Talk forum periodically erupts into flame wars.*



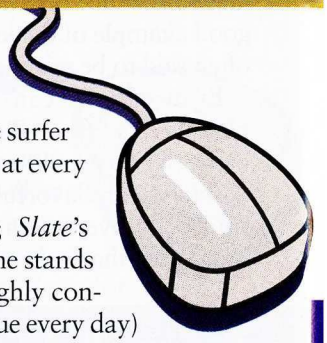
small as well, typically occupying a rectangle about 1 by 2 inches in the middle of the screen. Longer segments of video that would look sharper and occupy a larger portion of the screen are technically possible but would take impractically long to transmit. As it is, these 30-second video nuggets take a long time to download—for a computer chugging along with a 14.4 kilobit-per-second modem, the download will chew up typically 15 to 20 minutes, *Slate* warns.

Sometimes, however, this constraint makes little difference. Take *Slate*'s Varnish Remover column, which analyzes television ads. The Web reader can click on a link to download the video of the entire ad, not just an excerpt. During the presidential campaign, the column was devoted mainly to political TV commercials; now it has moved on to the kind of product ads that fill the screens in nonelection years, including Everready batteries and Levi's jeans, as well as two product categories—liquor and condoms—that recently were the subject of first-time-ever TV ad campaigns. The ability to view the ads and read the commentary at the same time gives this feature an almost scholarly value.

Multimedia links can also provide historical context. A *Slate* article by historian Michael Beschloss about the political problems that bedevil second-term presidents, for example, links not only to the Gallup poll's quarterly public-approval ratings for every president since Eisenhower but also to audio clips from two infamous moments in Richard Nixon's aborted second term: the "I am not a crook" passage from a speech he made while the Watergate scandal was unfolding, and his resignation address. The medium makes such additions uniquely possible; television delivers pictures without the intellectual depth that text provides; print cannot bring events back to life.

Lost in Space (and Time)

Browsing the current webzines yields the impression that no one has completely figured out how best to adapt a print tradition to electronic form. Simple matters such as knowing how to get from place to place and knowing whether an article is old or new seem to stymie the designer; a zine surfer must acclimate to different interfaces at every electronic publication.



Some differences are cosmetic; *Slate*'s maroon, gray, and white color scheme stands in sedate contrast to *HotWired*'s highly contrasting colors (a different glowing hue every day) and *Word*'s melange of moving images. Some entries into the field have yet to master Web basics. *IntellectualCapital*, which comes off as a weighty magazine of political and economic issues, has not yet figured out that long tables of contents on the home page are difficult to penetrate.

Webzines spawned by the print magazine establishment sometimes reveal unhelpful allegiance to print conventions. *Slate*, for example, assigns "page" numbers to articles. The idea is to make readers feel that they can navigate the way they do in print. But Web surfers don't generally think of online material as numbered pages, and this system seems anachronistic—as if Henry Ford had built a set of reins into the dashboard of the Model T. (*Computer-Mediated Communication Magazine* numbered its pages when it started up three years ago, says founder and editor John December, but abandoned the system because the numbers seemed arbitrary in a nonlinear medium.)

If *Slate* errs by trying to be too printlike, the opposite tendency mars *Word*, a New York–based lifestyle webzine. In *Word*, nothing stands still; the graphic images dance and shimmy, usually without any particular meaning. The table of contents looks like something from *TV Guide*, with six fine-print listings of articles arranged in columns under inscrutable department titles like "habit," "gigo," "pay," "machine," and "desire." Graphical paraphernalia seem goofy; a gallery of animated dancing toilets, for example, adorns a page of self-described stupid jokes.

Salon and *HotWired* have probably devised the most fully Web-like sites. *Salon's* main page presents links to the

webzine's departments: "Sharps & Flats" (music reviews); "Newsreal" (commentary on the news); "Media Circus" (media criticism); "Sneak Peeks" (book reviews) and "Taste" (food and wine). Clicking on one of those choices brings up a page with content divided into compartments, known as "frames." The main frame contains the article of the day; along the left-hand side of the screen a narrow vertical frame presents an index of every article in that department for the past month, any of which you can read with a click.

Different webzines have different approaches for displaying articles that are too long to fit on a single screen. *Slate* delivers an entire article at once, no matter how long it is, allowing readers to scroll up and down through it much as they would flip through the pages of a long article in a printed publication. *Salon* and *HotWired*, on the other hand, often present articles in segments. A *Salon* essay analyzing the prevalence of libertarianism on the Net, for example, leads off with the first 500 words, along with a link to click on to get the 2,500-word balance of the piece. *Salon* breaks other articles into multiple, equal-sized chunks, with no apparent logic to guide the partitioning.

Webzine designers face a dilemma. The surest way for any Web site to draw traffic is to change the content frequently—nothing feels as stale as an unchanged Web site. Too much churn, however, confuses a print-oriented reader.

The best online panels bring together thinkers who know what they're talking about, write well, and refrain from making personal attacks. For the Internet, that's a rare triple whammy.

Magazines as we have come to know them are defined by the issue date that anchors them in time; cover images and other cues help readers recognize what's new and what's old. And once an issue is read, it can be consigned to the trash or storage pile. Webzines treat time more cavalierly. It's not immediately apparent when you have already read something, so you find yourself revisiting the site in search of fresh material. And sometimes a label of "new" on the contents page indicates only a small addition to a department rather than an entirely new piece. *Slate* took a helpful step toward anchoring its articles in time by offering, as an option, a contents page that sorts articles by date.

The ease of dipping into a webzine's archives of past articles further muddies the reader's place in time. With last week's or last month's articles only a couple of clicks away, webzine sites make it about as easy to tap into their well of previously published material as their current issue. It is as if *Time* magazine came to the mailbox every week with a 100-pound box of carefully indexed back issues. The most current edition loses some of its primacy when stacked against all that history.

The best webzines are finding ways to update their material often while acknowledging many readers' preference for discrete "issues" pinned to a particular day or week. *Slate*, *Salon*, and *HotWired*, which change at least some of their content every weekday, all send out weekly e-mails summarizing the articles "now playing" at their sites; these notices go to all who have signed up for these webzines' (free) alert services. The e-mail contains hot links that allow recipients to jump immediately to read the piece that the blurb describes.

Who's Paying the Bills?

Most of the cost of publishing a conventional magazine goes to buy paper, operate the printing presses, and distribute the finished product through the mail and to newsstands, according to Christopher Harper, a journalism professor at New York University. A webzine incurs none of these. At first blush, therefore, any revenue that a webzine can produce "seems like free money," says Michael Mooradian, an analyst at Jupiter Communications, a market-research firm specializing in new media. *Salon*, which was launched in November 1995, began with one-tenth the capital that would have been required for a comparable national print magazine, asserts *Salon* founder David Talbott.

Nevertheless, whether webzines' unique attributes will lead to financial success—and hence long-term survival—remains an open question. Writers, editors, and computer programmers don't work for free. *Slate* has a staff of about two dozen, according to publisher Rogers Weed; *Salon*, says Talbot, is put out by 18 people. Thus maintaining a high-quality webzine requires a substantial flow of income from somewhere. The big webzines are still running on the momentum of their deep-pocketed founders—with Microsoft bankrolling *Slate*, and Apple Computer and Adobe Systems supporting the launch of *Salon*.

Print magazines make money in two basic ways: selling copies to readers and selling readers to advertisers. Neither source of revenue translates very well onto the Web. Internet users, steeped in an ethic of free information, are loath to pay for anything other than hooking into the Net itself.

Slate's saga shows that the day when webzines will charge for subscriptions seems, if anything, to be receding into the hazy future. When Microsoft launched *Slate* last June as a free service, the company warned that the deal was only temporary. Starting in November, *Slate* readers were going to have to pay $19.95 per year for the privilege. As Novem-

ber approached, however, *Slate* backed down. Access would continue to be free until February 1997, Microsoft announced, because the company had been unable to perfect the software needed to keep billing records. Cynics scoffed at that explanation, suspecting that Microsoft's real concern was a potential drop in readership.

And indeed, in January, Slate postponed this financial day of reckoning yet again—this time indefinitely. "Maybe in the future," wrote *Slate* editor Michael Kinsley, "people will happily pay for access to premium sites" on the Web, as they pay now for premium cable channels. But Kinsley acknowledged that with the possible exceptions of pornography and financial information, that day has not arrived. "Even in our headiest moments," he continued, "we couldn't convince ourselves that people lust for political and cultural commentary the way they lust for sex or money."

The analogy with cable TV is telling, says David Card, an interactive services analyst at the market-research firm International Data Corp. Premium channels like Home Box Office didn't really take off, he says, until free TV and basic cable channels were glutted with very-low-quality programing. Only then were millions of people willing to pay for a service that they had been receiving for free. There is still plenty of valuable and entertaining material on the Web that costs the user nothing, Card contends. As long as that is the case, webzines will find subscription sales a tough path.

"We couldn't convince ourselves that people lust for political and cultural commentary the way they lust for sex or money."—*Slate* editor Michael Kinsley, announcing that the webzine would remain free.

Web surfers have at least another year of free reading, analysts say. The only online publications that will be able to charge for access are those with gold-plated brand names that command an instant audience, says Jupiter's Mooradian. The *Wall Street Journal* has already begun charging for access to its online interactive edition; *Barron's* and ESPN might similarly get away with levying such fees for their financial and sports information.

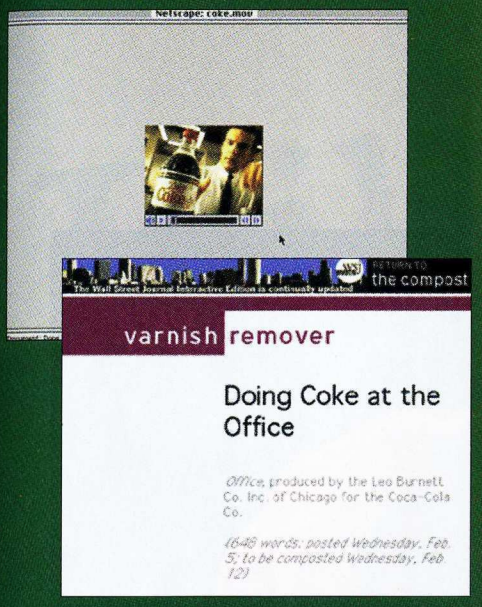
Meanwhile, most webzines are trying to make ends meet by tapping into the explosively growing market of Web-based advertising. Companies spent $55 million on Web ads in 1995 and $260 million in 1996, according to Mooradian at Jupiter. The total is expected to top $1 billion this year. Web advertising has great allure because readers can do more than simply gaze at a picture or read the copy—they can also click through to the advertiser's page, where they can request more information, download trial versions of a software product, or place a credit card order.

Such advertising appears in two basic forms: long-term sponsorship of a webzine's department, and banner ads that appear on the top of pages anywhere in the webzine. A successful example of a sponsorship is the relationship between *Salon* and Borders, the national bookstore chain. In return for sponsoring *Salon*'s book review page, Borders gets a sweet prize: reviews are accompanied by links to the bookstore's order forms. Click on the order form, fill in a credit card number and address, and within days the item arrives at your door. The bookstore, in turn, prints excerpts from *Salon* reviews on the bookmarks that it gives away to customers. Judging from *Salon*'s often-critical reviews, this cozy relationship has not seemed to compromise the webzine's editorial integrity.

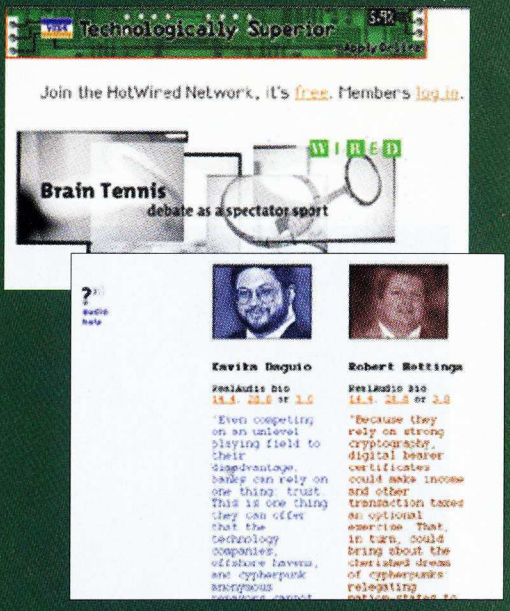
Still, webzines may have difficulty surviving on advertising dollars. A print magazine sells ad space by promoting the demographics of its readers. While publications like *Slate* and *Salon* attract an upscale audience—*Salon,* for example, claims that its readers have a median household income of $80,000—this profile does not stand out in bold relief from the Internet as a whole, which is still largely an affluent preserve. "*Slate* and *Salon* have great demographics, but on the Internet that's no big deal," says Mary Doyle, a new-media analyst at the market-research firm IDC/Link in New York. It therefore makes more sense for a company to place ads in sites that millions of people surf by—the Netscape home page, for example, or one of the major search sites such as Yahoo and Infoseek. In fact, Doyle says, webzines will skim off only a small fraction of the total Web ad revenue; 1996 advertising revenue for all webzines totaled a mere $13.5 million, she estimates, puny compared with the $61 million spent on ads at search sites.

Mooradian of Jupiter counters that webzines do have special appeal. A company selling Scotch, he says, is not going to find a general-purpose Web page very attractive as an advertising site, since so many Net users are under the legal drinking age. "A company like that is going to be much more likely to put an ad on *Slate* than on the Netscape home page," Mooradian says. And *Salon*, which claims a readership that is 50 percent female, should attract advertisers who would otherwise dismiss the Web as an inappropriate medium.

Advertising is a numbers game, and Web sites are still struggling to come up with the solid numbers advertisers want—namely, how many people visit a site. One way is to have readers register. All the top webzines require registration to enter their forum, or to sign up to receive e-mail notification of what is in the webzine. Such registration is free to the user and gives the webzine its most reliable tallies of how many people are reading it. *Slate*, for example maintains about 15,000 people on its e-mail list. The

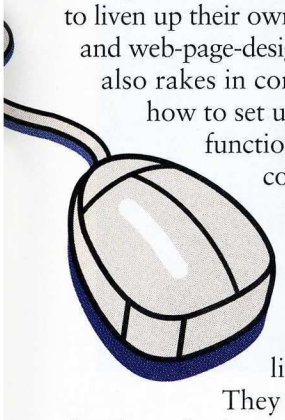


Tapping the medium's potential: Webzines have incorporated video only slowly; one smart use is in SLATE'S critiques of television ads (left). HOT-WIRED'S "Brain Tennis" (right) illustrates the Web's ability to showcase provocative debate.



webzine also claims that 50,000 to 60,000 different people visit the *Slate* site "on a semi-regular basis." *Salon* says more than 27,000 people have registered for its "Table Talk" forum. These are small numbers by magazine publishing standards; if advertisement is to sustain webzines, the companies placing the ads will need to believe that the Web is providing an added benefit beyond what they could get in print. An advertiser needs to be convinced, for example, that buying space on a webzine will do the company more good than an ad that reaches the same number of people in print.

Other streams of income are also possible. *Word*, for example, licenses some of its articles to companies who want to liven up their own corporate Web pages. The Net access and web-page-design company that owns *Word*—ICon—also rakes in consulting fees for dispensing advice on how to set up an attention-getting Web site. *Word* functions as a promotional tool for its parent company and therefore does not need to make money in its own right.



Growing Up

Webzines face a tough battle in establishing themselves as a viable medium. They are certainly nowhere near usurping the place of print publications (not a goal that they espouse in any case).

Technological innovations are arising faster than webzines incorporate them. RealAudio has been available for two years, yet few webzines offer sound links. The reason lies partly in the low quality of Net access that most people have. Only about one U.S. household in five has a modem, and that will rise to about one in four by 1999, according to E-land, a company that compiles Internet usage data. And a substantial number of these modems crawl at 14.4 kilobits per second. At that speed, downloading graphics—not to mention sound and video—is an exercise in finger-drumming tedium, leading to more frustration than gratification.

Looking into the future, some predict the convergence of webzines with print. Picture an ultra-lightweight, ultraslim computer display that connects to the Internet and that receives data through a high-speed wireless transmission. This tablet would prove almost as portable as a print magazine but would offer all the added value that the online publications provide.

Journalistically, webzines have some growing up to do. The dearth of original reporting forces the webzines to establish identities, say some commentators, not by delivering information but by striking poses—*Suck* as an arbiter of what is good in Net journalism, *Slate* with its inside-the-beltway, know-it-all punditry, *Salon* with its literary pretensions. The need to keep readers on a page instead of hopping off through a hyperlink leads writers and editors to indulge in a kind of substanceless edginess. "The problem with these publications is that they're nothing but attitude," complains media critic Kennedy.

At the same time, the new media do provide a chance to make a clean break from print journalism, which the public has harshly criticized for flaws ranging from an obsession with violence to overreliance on information handouts by government officials and corporations. "The Web's great adventure is that it puts the reader in control," says NYU's Harper, whose present status as new-media scholar comes after a 20-year career as reporter for Associated Press, *Newsweek*, and ABC News's *20/20*. "The Web isn't the end-all and be-all, but it does gives us a wonderful opportunity to reexamine how we tell stories."

VISIT OUR HOME PAGE TO FIND LINKS ON THE INTERNET TO SOURCES OF INFORMATION RELATED TO THIS ARTICLE:
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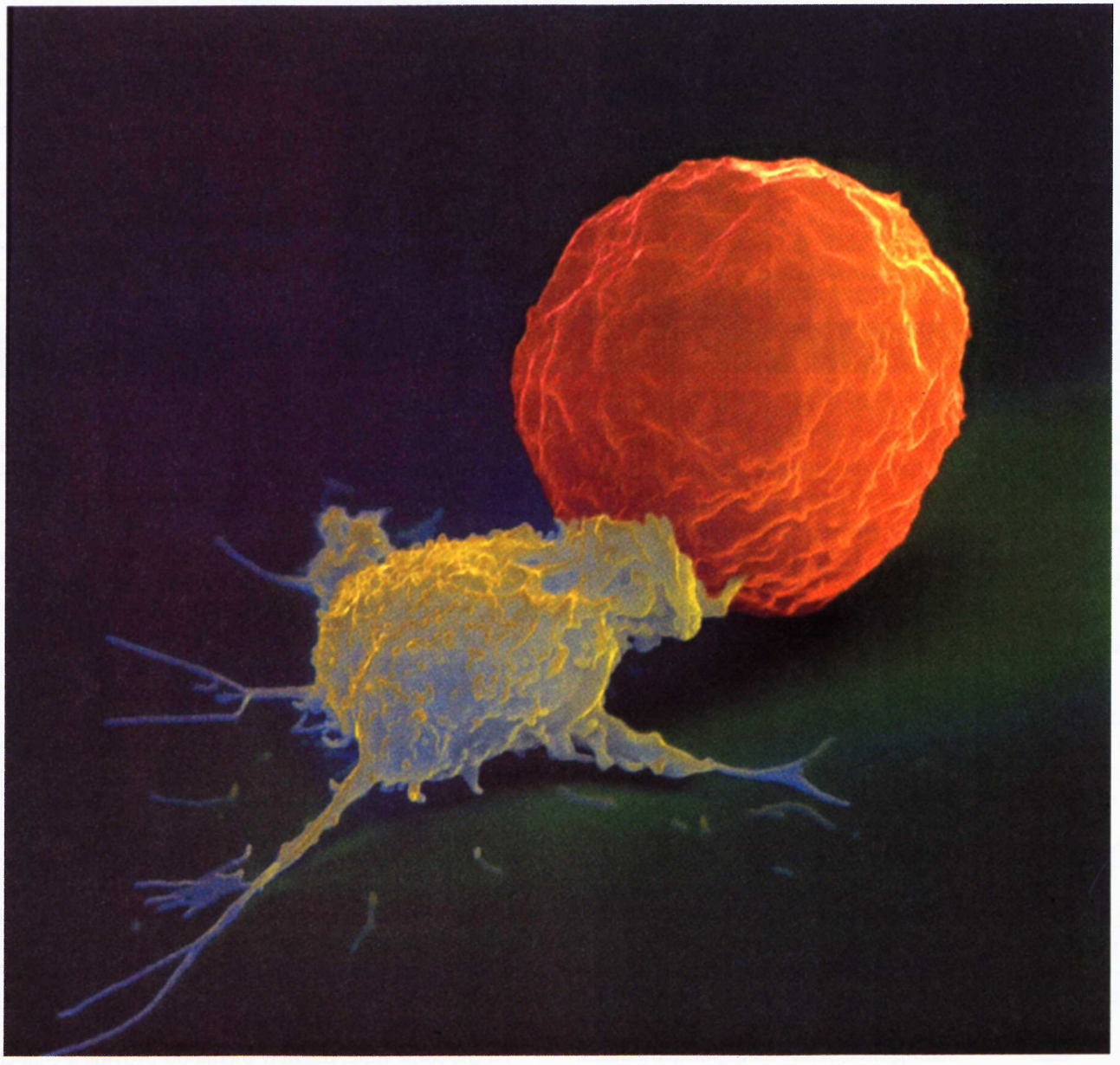


ON THE OFFENSIVE: IN THIS IMAGE FROM A SCANNING-ELECTRON MICROSCOPE, AN IMMUNE CELL BEGINS TO ATTACK A CANCER CELL (ORANGE).

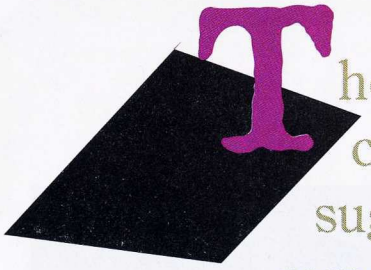
PHOTO: MECKES/OTTAWA/PHOTO RESEARCHERS INC.

Killing the Last Cancer Cell

Recognizing that tumor cells lurking in the body after cancer treatment will cause a relapse of cancer, scientists are working to employ nature's army—the immune system—to destroy remaining enemy outposts.

EARLY in this century, patients with cancer would often seek medical attention only in the final stages of their disease, after their tumors had become massive. Surgeons would attempt to remove these tumors to alleviate their patients' pain. But since sterile operative techniques were in their infancy and the discovery of antibiotics almost half a century away, such surgery often caused massive and frequently fatal infections. In a few instances, however, tumor remnants of infected patients would disappear, leaving them healthy and doctors puzzled. Today, after decades of research into how the immune system works, scientists have learned that the seemingly miraculous cures resulted from the infections themselves, which set in motion complex immune reactions.

BY RONALD M. KLINE AND SUNIL CHADA



The immune system's elegant and complex methods of attacking invaders suggest a variety of ways to assail remaining bits of malignancies.

Understanding the relationship between cancer and the immune system—whose purpose is to find and destroy any abnormal cells in an organism among a mass of normal ones—has resulted partly from so-called "experiments of nature." A few diseases involving immune deficiencies are associated with higher rates of cancer, for example. A person infected with HIV, for instance, is 100 times more likely to develop a malignancy than an uninfected person. Also, organ-transplant recipients treated for a long time with drugs that suppress the immune system, thereby preventing rejection of the new organs, are many times more likely to develop cancer than the rest of the population. In fact, an elegant demonstration of the immune system's role in protecting against cancer is the fact that tumors occasionally regress when doctors remove immunosuppressing drugs.

Armed with such discoveries as well as modern biotechnology techniques, researchers have begun using several elements of the immune system to systematically destroy tumor cells. (Of course, immunotherapy is only one of a number of innovative ideas in cancer treatment that hold significant promise. The public investment into cancer research since the Nixon administration declared war on cancer in 1971 is finally starting to produce a variety of innovative techniques, such as methods that exploit the genetics of how a cell becomes malignant.) The work, being conducted on both animal models and people with cancers difficult to eliminate by traditional means, has a long way to go but suggests a more effective way of treating many cancers in the future.

The Problem with Recurrent Cancer

The standard methods for eliminating malignant tumors have long been surgery, radiation, and chemotherapy. The underlying crude assumption is that doctors can generally destroy a cancer without losing the patient to the therapy's toxic effects. Of course, as researchers have developed supportive care such as powerful antibiotics and growth factors—natural body proteins that can be manufactured using genetic-engineering techniques and that cause the white-blood-cell count (which plummets after treatments) to recover more quickly—doctors have been able to administer more intensive chemotherapy. These treatments have played a role in the recent good news that the number of U.S. cancer deaths has finally dropped for several consecutive years. Still, 500,000 U.S. residents annually die of malignancies—a number hard on the heels of the country's number-one killer, cardiovascular disease.

For everyone who has witnessed cancer firsthand—whether as patient, family member, friend, or medical professional—one of the most worrisome and disheartening aspects is that while today's therapies can generally eradicate all measurable evidence of disease initially, any remaining cells may proliferate and cause a relapse of cancer. And because the first set of remaining cells has resisted chemotherapy, their offspring have a selective advantage to do the same, leaving the person with a recurrence of cancer that is often widespread and much less easily treated with chemotherapy or other techniques.

A critical need, therefore, is to find and eliminate the few remaining cancer cells left viable after conventional therapy. The immune system's elegant and complex methods of attacking invaders suggest a variety of ways to assail the remaining bits of malignancies. (Another goal is to discard today's techniques altogether in favor of an entirely different method. But eliminating treatments that now work better than anything else is not judicious until viable alternatives develop.)

At its simplest level, the immune system discriminates between "self" and "nonself" and destroys the latter. In most responses, the system relies partly on antibodies—proteins with two specialized ends. One end of an antibody binds to the infecting cell or virus while the other end attracts immune cells that engulf and digest the invader. The attack also relies on different immune cells, which, upon contact with foreign cells, secrete compounds that make the offenders' membranes porous so that their vital contents leak out and the cells eventually die.

With this general understanding of the immune system and knowledge of the early reports of tumor regressions after infection, in the 1960s and '70s clinicians injected some solid tumors with killed or weakened microbes, such as BCG (bacille Calmette-Guérin, an altered form of tuberculosis) and *Cornybacteria* (the cause of diphtheria), in the

RONALD M. KLINE is director of the pediatric blood and marrow transplantation program at the University of Louisville and Kosair Children's Hospital. He conducts immunotherapy research as part of his work treating patients with cancer. SUNIL CHADA is a molecular immunologist studying gene-therapy approaches for treating HIV and cancer at Chiron Technologies' Center for Gene Therapy, which is based in San Diego.

hope that such outside organisms would stimulate an immune response. And indeed they did, sometimes destroying the tumor. Although the results were inconsistent, the work demonstrated that "immunotherapy" might someday have a place in the cancer-fighting armamentarium.

Toward Specific Immune Therapy

Then along came genetic engineering and the recognition of its value in identifying and manufacturing proteins called cytokines. Some of these can act as anticancer agents because they regulate the activation of immune cells. They essentially put the immune system at a higher state of alertness so that it can better detect tumor cells. Researchers had discovered some cytokines in the mid 1970s, before the era of genetic engineering, but that technology made possible the production of a large enough quantity of the proteins for study and treatment.

Over the years, investigators have identified several cytokines that lead to the destruction of tumor cells. Indeed, the U.S. Food and Drug Administration has approved the intravenous use of the cytokine interleukin-2 for this purpose against kidney cancer. Researchers have also found this cytokine can help against one form of leukemia and malignant melanoma, and are studying its efficacy against a broad range of other cancers. And scientists have discovered that the cytokine alpha interferon can activate immune cells against a form of leukemia. Although for reasons not yet understood investigators have found that cytokine injections generally induce responses in only 20 to 30 percent of patients, researchers worldwide are continuing to explore which of a large variety of tumors, prognostic factors, doses, and dose schedules work best with particular cytokines.

Meanwhile, following some early work injecting cytokines to fight cancer, some scientists recognized that the amount of immune-cell activation that can take place in the body through cytokine injection is limited by the dose of cytokines that can be administered that way. The treatment's side effects, such as alternating fever and chills, low blood pressure, and difficulty in breathing, can become severe enough that patients need to stop the therapy. The investigators thought a way to raise the amount of activated immune cells would be to identify some of those cells, remove a few from the body, and mix them with a high dose of cytokines in a test tube. The idea was that the resulting large mass of activated immune cells, when infused back into the body, would travel to tumor sites and destroy cancer cells.

In 1982 Elizabeth Grimm, then a cancer expert at the National Cancer Institute (NCI), and two colleagues were the first to identify a kind of immune cell—which they labeled a lymphokine-activated killer (LAK) cell—that led to the death of tumor cells. Using the cytokine interleukin-2, the team next activated quantities of LAK cells in test tubes. Working in the laboratory of Steven Rosenberg, chief of NCI's surgery branch, the group ultimately found that LAK infusions destroyed cancer cells, especially those associated with malignant melanoma and kidney cancer. But other researchers concluded that the effects were no stronger than those seen from simply injecting interleukin-2. Apparently generating LAK cells outside the body was no more effective that creating them within the body through infusions of interleukin-2.

Then in 1986 Rosenberg isolated an immune cell from inside a tumor itself. Calling this cell a tumor-infiltrating lymphocyte (TIL), he postulated that it recognizes proteins unique to a tumor, moves into that entity, and attempts to generate an immune response. He extracted TIL cells from a surgically removed tumor and, in a test tube using interleukin-2, stimulated their growth up to about 100 times their original number. After this process, which took three weeks, Rosenberg injected the complete mass of TIL cells

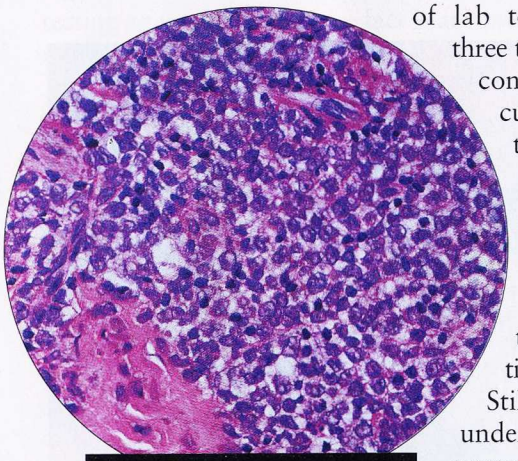
PHARMACEUTICAL COMPANIES ENGINEER ESCHERICHIA COLI BACTERIA TO PRODUCE LARGE QUANTITIES OF INTERLEUKIN-2 (SHOWN AS PINK BODIES), AN IMMUNE-CELL PROTEIN. DOCTORS ADMINISTER THE IL-2 TO PATIENTS WITH ANY OF A VARIETY OF CANCERS, IN CONJUNCTION WITH OTHER THERAPIES.

PHOTO: SECCHI-LECAQUE-ROUSSEL-UCLAF/CNRI/SCIENCE PHOTO LIBRARY

into animal models and later patients. The therapy was more potent than LAK treatments, with the tumors in 11 of 20 patients shrinking or disappearing altogether.

In follow-up research to determine why the TIL technique didn't always work as expected, however, in 1990 Richard Barth of the same laboratory determined that TIL cells do not kill tumor cells directly. Instead, after traveling to the tumor site they secrete more cytokines, such as tumor necrosis factor (TNF) and gamma interferon. These presumably recruit still other elements of the immune system in an attempt to destroy the tumor—an operation analogous to a reconnaissance team finding an enemy and then firing flares to bring reinforcements. Armed with this knowledge, in a subsequent experiment the lab tried to genetically engineer TIL cells to raise their secretion of TNF and gamma interferon. The idea was that the manufactured material, after being injected into the body, would home to areas surrounding malignant melanoma tumors—a particularly virulent form of cancer. But the researchers couldn't consistently engineer the TIL cells as they wanted to.

Interest in the method, as well as in injecting amplified but unaltered TIL, has subsequently waned because of such practical difficulties. Moreover, growing TIL cells is costly because of extensive involvement of lab technicians over three to six weeks, and contamination of cultures with bacteria or fungi is always possible. Repeated surgeries are also required to provide tumor cells to stimulate continual TIL growth. Still, the notion underlying Barth's research—genetically manipulating tumor cells—has provided the intellectual impetus for the next stage of work: cancer vaccines.



INVESTIGATORS DISCOVERED THAT INJECTING LARGE CONCENTRATIONS OF A TYPE OF IMMUNE CELL FOUND WITHIN TUMORS SOMETIMES ENABLED THOSE TUMORS TO SHRINK OR DISAPPEAR. HERE THE IMMUNE CELL, CALLED A TUMOR-INFILTRATING LYMPHOCYTE (DARK PINK), LIES AMID CANCER CELLS.

Fighting Tumors with Their Own Kind

When most people think of vaccines, their reference is to doctors giving these agents to prevent illness in the first place. But vaccines can be more than that, since they are simply modified infectious agents, or portions of agents, that stimulate an immune response when administered into a body. Thus a vaccine can be given after a person is sick, with the intention of stimulating an immune response strong enough to enable the patient to heal and then stay well. This approach underlies the idea of cancer vaccines.

The method used to construct most cancer vaccines has entailed introducing genes for cytokines into tumor cells and injecting these into the body. (To ensure safety, they have been treated with high-dose radiation so they cannot proliferate but can still carry out functions such as releasing the cytokines.) Researchers believe that physically bringing together these agents, plus immune cells that are always circulating in the body, approximates what happens during the natural generation of an immune response against cancer. The additional tumor cells should theoretically secrete extra-large doses of cytokines that will in turn activate heightened immune responses. And theoretically, the treatment should work for a long time, since immune responses produce other cells known as memory T cells, which provide long-term immunity.

Experiments introducing cytokine genes into animals' tumor cells began in the late 1980s, with researchers having now tested more than 10 of some 50 isolated cytokines. Working with mice, scientists have found that 4 cytokine genes—those that produce interleukin-2, interleukin-4, gamma interferon, and GM-CSF—suppress the growth of existing malignancies of various kinds, including melanoma, colon, kidney, breast, and leukemia.

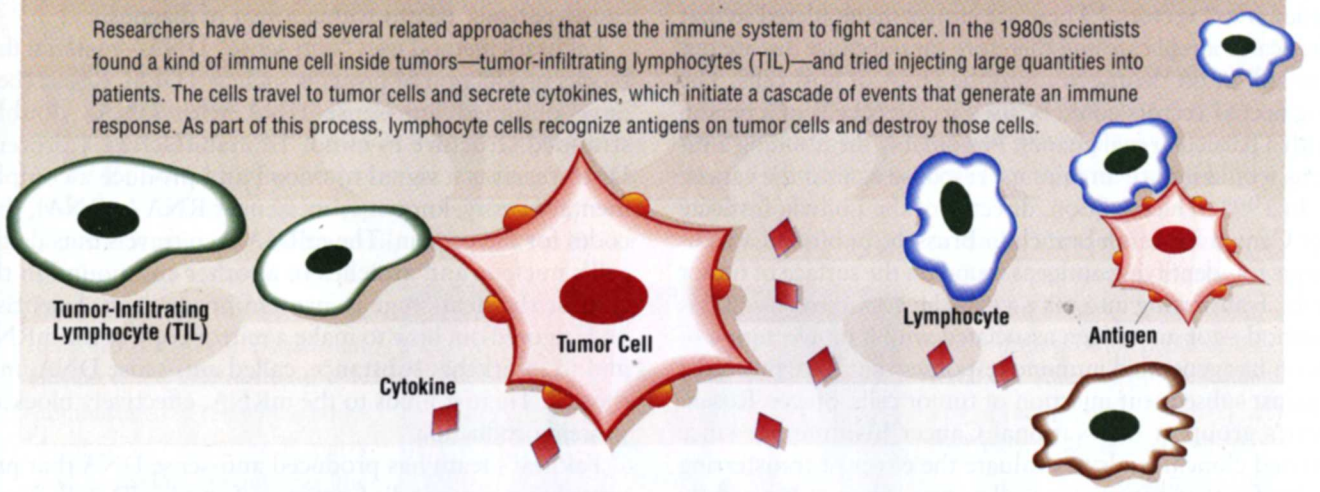
The encouraging results have led to more than 80 human clinical trials. Researchers have treated over 100 people with interleukin-2 vaccines, more than 80 with GM-CSF, and 30-plus with gamma interferon. The investigators are just starting to publish their findings. In the first trial to be described that has had a significant number of patients, for instance, investigators at Somatix of Alameda, Calif., inserted the GM-CSF gene into tumor cells of more than 40 extremely sick patients for whom other treatments for malignant melanoma had failed. The researchers then injected the modified cells into the patients. While because of the stage of their illness many of the patients died during the treatment period, 3 of 13 people have had some tumors partly or completely shrink after therapy. Since ordinarily none of these tumors would have been expected to shrink, that number is encouraging enough to suggest that further trials are warranted.

Still, the general technique is not ideal to use across the board, since it requires genetically engineering each patient's tumor cells. That's necessary because an individual will reject another individual's cells. To avoid this problem, some researchers have come up with the idea of using something other than whole cells: tumor antigens—proteins found on the surface of tumor cells. Antigens, which are not necessarily unique to individuals and therefore not something that bodies reject, lead to an immune response against abnormal entities such as tumors. If investigators can figure

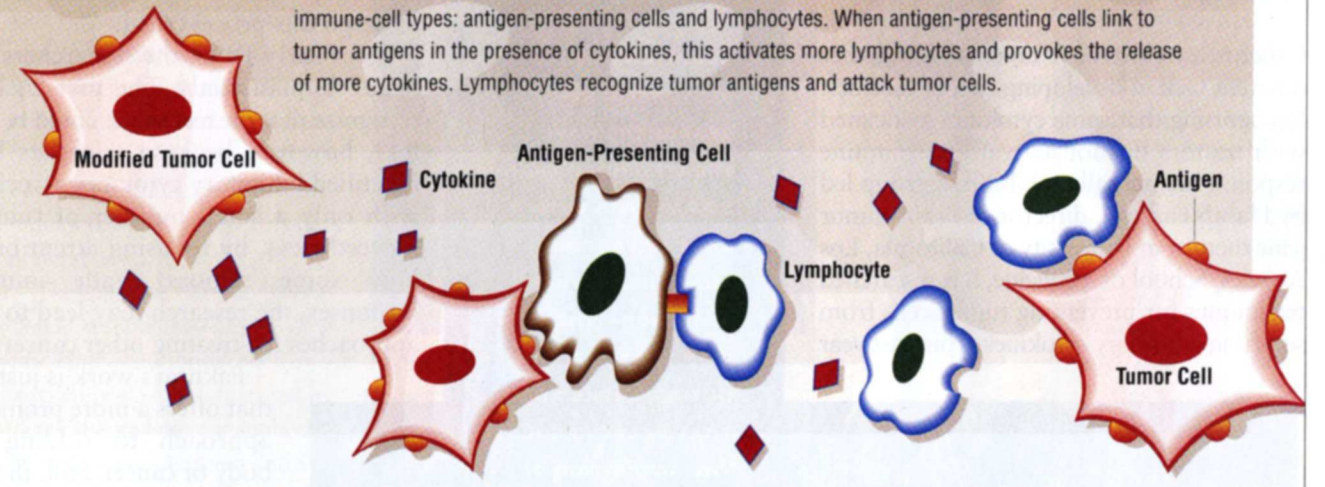
PHOTO: LABORATORY OF STEVEN ROSENBERG, NATIONAL CANCER INSTITUTE

MOBILIZING THE NEW CANCER ARMY

Researchers have devised several related approaches that use the immune system to fight cancer. In the 1980s scientists found a kind of immune cell inside tumors—tumor-infiltrating lymphocytes (TIL)—and tried injecting large quantities into patients. The cells travel to tumor cells and secrete cytokines, which initiate a cascade of events that generate an immune response. As part of this process, lymphocyte cells recognize antigens on tumor cells and destroy those cells.



TIL injections proved complex and costly. Investigators have therefore started examining the details of the immune response to devise other ways to elicit it. Many trials now focus on injecting tumor cells modified to secrete a large number of one or another kind of cytokine. The cytokines recruit two immune-cell types: antigen-presenting cells and lymphocytes. When antigen-presenting cells link to tumor antigens in the presence of cytokines, this activates more lymphocytes and provokes the release of more cytokines. Lymphocytes recognize tumor antigens and attack tumor cells.



Modifying tumor cells still has a hitch: it requires genetic engineering of each person's cells. Some researchers are trying to circumvent this by injecting DNA containing genes for cytokines and tumor antigens—which aren't necessarily unique to individuals—into patients' normal cells. These genes then produce the proteins, which in turn initiate the same immune response as above.

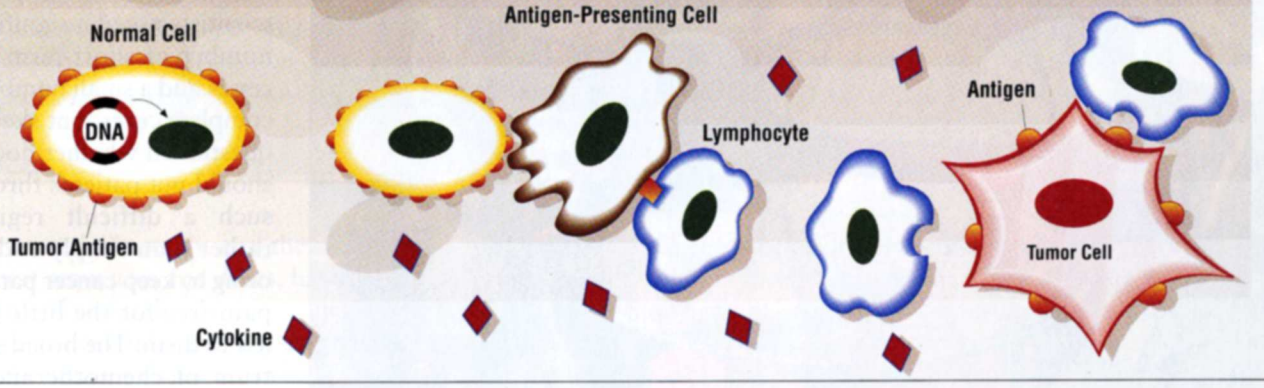


ILLUSTRATION: DEB PERUGI DESIGN

out the antigens produced by particular kinds of tumors, the thinking goes, large amounts of such compounds, or better yet, their genes, could be placed, along with cytokine genes, into "vectors." These are viruses manipulated so that they cannot replicate and therefore cannot cause disease but can still insert themselves into the DNA of host cells. The engineered vectors could be used to infect cells in a person with a particular malignancy. Presumably the resulting antigens would induce an immune response against the cancer.

In 1991, Thierry Boon, director of the Ludwig Institute for Cancer Research branch in Brussels, published a technique for identifying antigens found on the surface of tumor cells. Transferring into mice a gene he discovered using this method—for an antigen associated with a mouse tumor—Boon has generated immune responses that have protected against subsequent injection of tumor cells. Steven Rosenberg's group at the National Cancer Institute has since started clinical trials to evaluate the effect of transferring genes for that antigen, as well as two others subsequently discovered, into melanoma patients. Results are not yet available.

Inhibiting Inhibitors

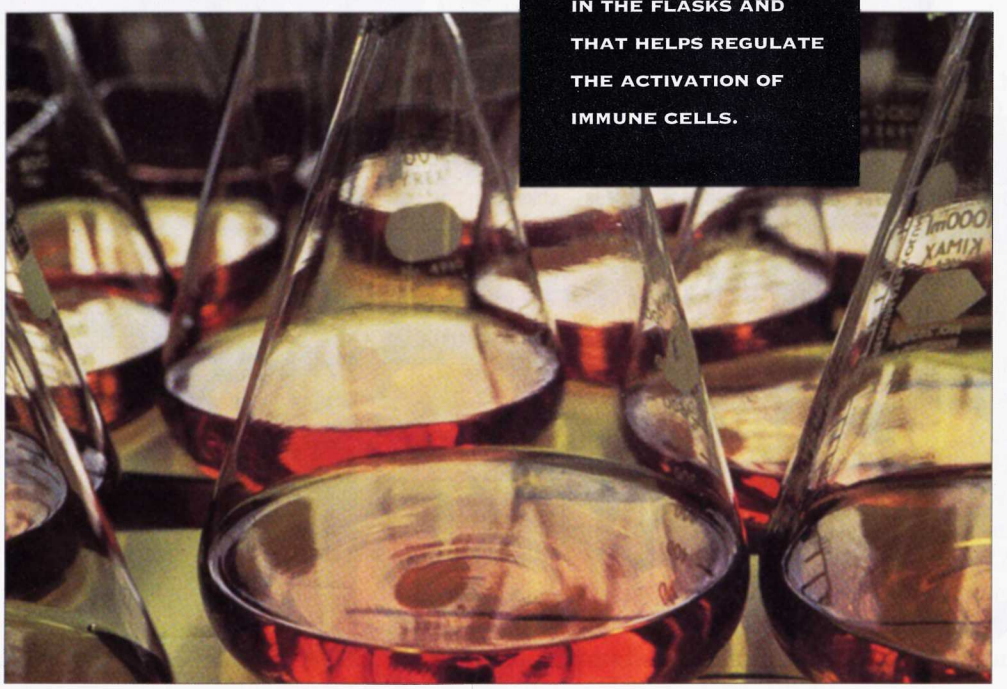
Other researchers have taken an altogether different tack in developing cancer vaccines. Recognizing that some cytokines associated with tumors do not activate an immune response but actually inhibit it, a group led by Habib Fakhrai, director of brain-tumor gene therapy at University of California, Los Angeles, School of Medicine, has researched techniques for preventing tumor cells from secreting inhibitory cytokines. This past year Fakhrai published an approach for treating an aggressive brain tumor that secretes an inhibitory cytokine called transforming growth factor-beta (TGF-ß). This cancer usually causes patients' deaths within a year of diagnosis.

Fakhrai's method uses "anti-sense" DNA—material that blocks production of proteins such as TGF-ß. Researchers have designed anti-sense DNA with DNA's double-stranded structure in mind. To manufacture a protein, DNA receives a signal to uncoil and produce a complementary entity, known as messenger RNA (mRNA), that codes for the protein. The mRNA then travels outside the cell's nucleus and attaches to another compound in the cell for the next stage in protein production. Scientists have figured out how to make a mirror copy of the mRNA and to insert that substance, called anti-sense DNA, into the cell. There it binds to the mRNA, effectively blocking protein production.

Fakhrai's team has produced anti-sense DNA that prevents brain-tumor cells from manufacturing TGF-ß. Working with rats with brain tumors, the group found that all 11 animals injected with vectors containing the anti-sense DNA rejected their growing tumors and survived, while every rat that did not undergo this process died.

As of early 1997, the researchers had begun human trials. The investigators recognize that the technique could be limited, however, because scientists have identified inhibitory cytokines associated with only a small number of tumors. Nevertheless, by focusing attention on how some tumors evade immune responses, the research may lead to new approaches for treating other cancers.

IN AN ATTEMPT TO HEIGHTEN IMMUNE RESPONSES, RESEARCHERS HAVE TREATED MORE THAN 30 PATIENTS WITH A CANCER VACCINE THAT PRODUCES INTERFERON—THE PROTEIN THAT IS SHOWN IN THE FLASKS AND THAT HELPS REGULATE THE ACTIVATION OF IMMUNE CELLS.



Fakhrai's work is just one that offers a more promising approach to ridding the body of cancer. Still, the status of immunotherapy research today resembles that of chemotherapy soon after investigators first demonstrated its effectiveness in 1948. In the 1950s, scientists noted a significant number of short-term successes and a small number of complete cures, but skeptics questioned whether doctors should put patients through such a difficult regimen rather than simply endeavoring to keep cancer patients pain-free for the little time left to them. The broad spectrum of chemotherapeutic

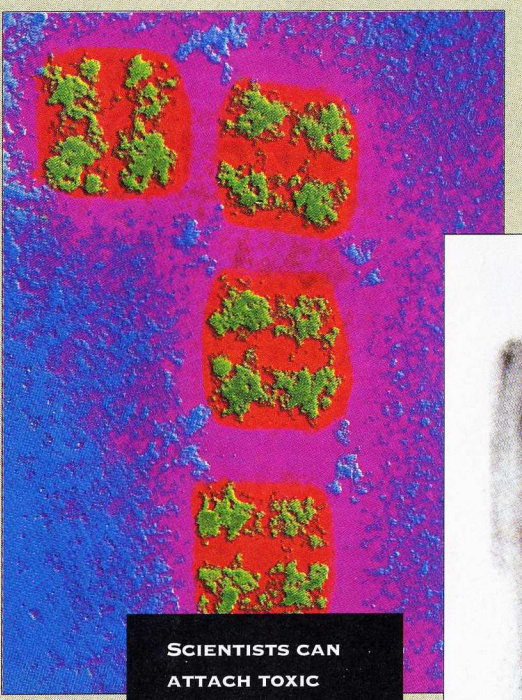
PHOTOGRAPH: NCI/SCIENCE SOURCE/PHOTO RESEARCHERS INC.

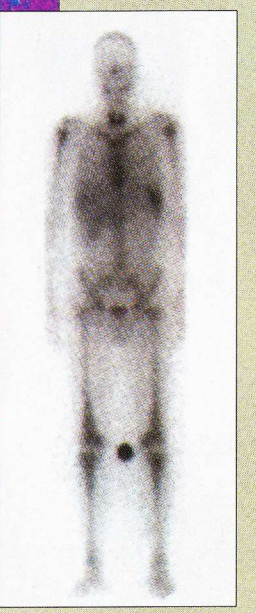
Strengthening Traditional Cancer Therapy

WHILE many researchers are manipulating the immune system to develop treatments to sop up the cancer remnants following chemotherapy, some investigators are working with the products of immune cells to improve chemotherapy itself. The idea is to link antibodies to the toxic agents to deliver the resulting material only to tumor cells. This could eliminate dangerous systemic effects that ensue when chemotherapy is administered to the whole body: damage to critical body parts such as the kidneys, the liver, the heart, the lungs, and bone marrow, which produces the white blood cells that fight disease. Then doctors could safely provide higher doses of chemotherapy, or treatments with more toxic compounds. And by marrying antibodies to toxic radioactive agents, physicians also might be able to safely raise doses of radiation when that treatment is preferable.

The approach relies on "monoclonal" antibodies—any of a specific kind of antibody, such as one that fights chicken pox—manufactured by a genetically identical population of antibody-secreting cells. In 1975 Cesar Milstein and Georges Kohler, both of the Medical Research Council's Laboratory of Molecular Biology in Cambridge, England, announced they had developed a technique to produce nearly unlimited quantities of monoclonal antibodies. Investigators quickly recognized that if scientists could obtain antibodies directed against particular tumor cells, the new technology—for which Milstein and Kohler received the Nobel Prize in physiology or medicine in 1984—could then manufacture enough copies to attach to toxic compounds. Injected into patients, the antibodies in the resulting "immunotoxins" would then go on seek-and-destroy missions, guiding their deadly cargo only to tumor cells.

Early clinical studies, at a variety of institutions on several hundred patients, are starting to show that in many kinds of cancer, immunotoxins produce less toxic side effects than chemotherapy or radiation used alone. Further research will examine whether immunotoxins are a more effective cancer treatment. So far, as has occurred with other immunotherapy methods, researchers have found that immunotoxins can eradicate individual cancer cells among masses of normal ones.





SCIENTISTS CAN ATTACH TOXIC COMPOUNDS TO MONOCLONAL, OR GENETICALLY IDENTICAL, ANTIBODIES (ABOVE) AND THUS DIRECT THE POISONS AGAINST CANCER CELLS. IN A PATIENT WITH LEUKEMIA, THE RESULTING IMMUNOTOXINS (DARKER AREAS IN BONE MARROW, ABOVE RIGHT) LED TO REMISSION OF THE DISEASE.

Researchers at various institutions have also linked monoclonal antibodies to low-energy and therefore nontoxic radioactive compounds, and used these to detect aggregations of different tumor cells in the body. Under the influence of radiation, those cells generate a bright spot that wouldn't normally show up on an x-ray or CT scan. Improved detection means a better ability to direct cancer therapy. ■

agents available today, and the current understanding of the best sequences and doses, have required almost a half century of research.

Investigators today similarly do not understand specifically how the immune response can best be manipulated to attack cancers, nor what treatment methods are most appropriate and practical for particular tumors. A long period of trial and error lies ahead. But investigators have taken the first difficult step: laying the intellectual groundwork for fighting cancer by systematically generating an immune response. ■

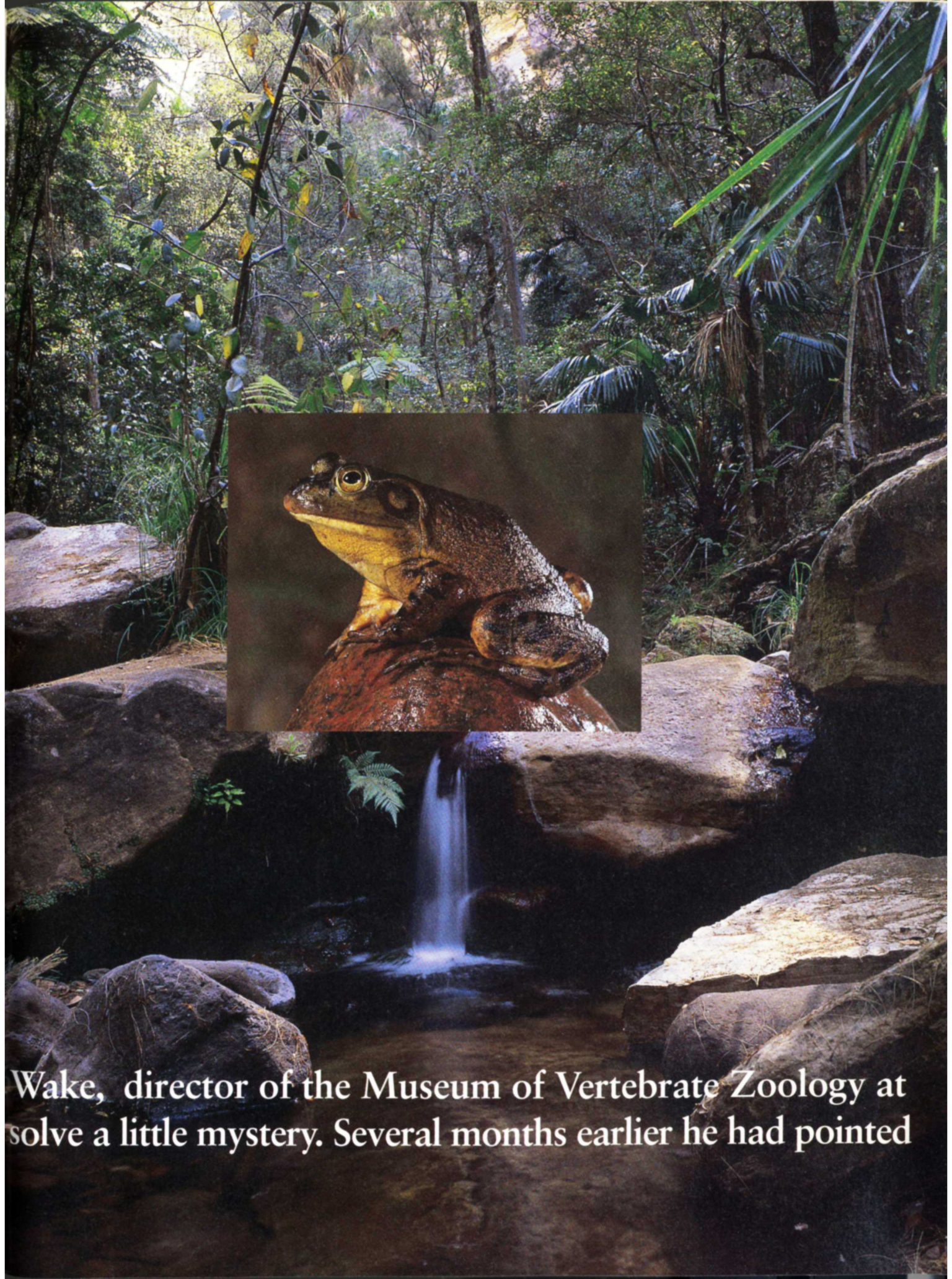
PHOTOS: CNRI SCIENCE PHOTO LIBRARY; DAVID SCHEINBERG AND CHAITANYA DIVGI/MEMORIAL SLOAN-KETTERING CANCER CENTER

The Case of the Vanishing frogs

ARE THE WORLD'S AMPHIBIANS—VULNERABLE TO ECOLOGICAL CHANGES IN WATER AND ON LAND—ACTING LIKE CANARIES IN A COAL MINE, WARNING US OF ENVIRONMENTAL DANGERS BELOW THE THRESHOLD OF HUMAN PERCEPTION?

In the summer of 1982, Davi
the University of California at Berkeley, set out t

By Timothy R. Halliday and W. Ronald Heyer



Wake, director of the Museum of Vertebrate Zoology at
solve a little mystery. Several months earlier he had pointed

Are amphibian declines permanent

THIS SPECKLED YELLOW MOUNTAIN FROG, *RANA MUSCOSA*, DISAPPEARED FROM ITS SIERRA NEVADA HABITAT FOR NO KNOWN REASON. FEARING THE PHENOMENON MIGHT BE PART OF A LARGER PATTERN, HERPETOLOGISTS LAUNCHED A GLOBAL INVESTIGATION.

David Green, then a postdoctoral fellow, to a site in the nearby Sierra Nevada that Wake knew to be abundant in *Rana muscosa*, a mottled yellow and brown frog Green was studying because of its unusually broken distribution patterns. But when Green reached the designated location, he couldn't find a single specimen.

Puzzled by Green's account, Wake decided to accompany him to the site, assuming he had simply missed it the first time. But when they arrived, Wake, too, was surprised to find that all the adults had disappeared and only a couple of tadpoles remained.

Wake and his other students soon began to notice similar disappearances at other popular frog localities in central and northern California. Wake wondered if he had stumbled upon a bigger puzzle: Was this decline in amphibian populations occurring only in California, or was it part of some larger pattern?

By coincidence, the First World Congress of Herpetology was scheduled to take place later that year in Canterbury, England. So Wake seized the opportunity to discuss his disturbing observations with other herpetologists. What he discovered, to his dismay, was that many of the attendees had witnessed the same phenomenon in scattered areas around the globe.

Wake took their reports and his own to the next meeting of the National Academy of Sciences Board of Biology, to which he belonged, and convinced its members to assemble a group of leading international amphibian experts to evaluate the evidence. The group, which convened in February 1990 in Irvine, Calif., quickly concluded that although most of the evidence for amphibian declines was anecdotal, the sheer number of widely dispersed informal reports indicated that the situation could be an environmental emergency, and that an international working group should conduct a full scientific investigation.

By the end of the year, after approaching several potential sponsors, Wake created the Declining Amphibian Populations Task Force (DAPTF) under the aegis of the Species Survival Commission of the World Conservation Union, an international organization comprising more than 500 environmental groups including the U.S. Fish and Wildlife Service and the U.S. National Park Service. Based at the Open University in Milton Keynes, England, the task force recruited more than 1,200 scientists to determine whether declining amphibian populations will simply rebound as part of some normal cycle or whether they truly are disappearing from the face of the earth.

Why We Care about the Victims

One reason so many amphibian biologists were eager to join the task force was simply because they were worried they might be losing their objects of study. But they were even more concerned for other reasons that everyone can appreciate. The first is the ethical consideration that amphibians have the right to exist. If people are responsible for amphibian disappearances, then people have a moral obligation to prevent them. Most religious traditions assign value to all living organisms. Even Judeo-Christianity, which espouses that humans are a special creation of God and are given dominion over the rest of the living organisms on earth, teaches that this relationship should be a stewardship, not a slaughter.

Second, amphibians are fascinating organisms that interact in complex ways with each other and their environments. Consider the life history of the Central American strawberry poison frog *Dendrobates pumilio*. At the beginning of their reproductive cycle, males call for females from

TIMOTHY R. HALLIDAY is the international director and W. RONALD HEYER is chair of the Declining Amphibian Populations Task Force, based at the Open University in Milton Keynes, England.

VALUABLE BIOLOGICAL INFORMATION IS FORFEITED FOREVER WHEN THE EARTH LOSES UNIQUE CREATURES SUCH AS THE STRAWBERRY POISON FROG (NEAR LEFT), WHICH TRANSPORTS NEWBORN TADPOLES ON ITS BACK, OR THE GASTRIC BROODING FROG (FAR LEFT), WHICH HATCHES EGGS IN ITS STOMACH.

perches on the tropical forest floor. After mating, the female lays her eggs in the forest's leaf litter. The father then revisits the eggs and keeps them moist with bladder water. When the eggs hatch into tadpoles, the mother carries them on her back and deposits each one into a tiny pool of water, often dew that collects at the base of bromeliad leaves. Because there is seldom enough food for even a single tadpole in these pools, the mother revisits each one every few days and lays an unfertilized egg for her offspring to eat. As the frogs mature, they synthesize poison toxins in their brightly colored skin from compounds found in the native arthropods on which they feed. If such frog species disappear, we lose valuable information about life on earth.

Third, amphibians may provide direct benefit to humans. One example is the gastric brooding frog, *Rheobatrachus silus,* of Queensland, Australia. After the female's eggs are fertilized, she swallows them and uses her stomach as a brood pouch, somehow switching off her digestive enzymes during the incubation period. Knowledge of such an enzyme-suppression mechanism might have proven helpful to people suffering from gastric ulcers. Unfortunately, while these and other biological aspects of *R. silus* were being investigated, the species disappeared from its natural environment, and all specimens in the laboratory died. For a rough idea of what we'd be missing if many such species disappeared, consider some benefits that have already been realized, including a pain killer recently derived from poison-frog toxins and a nonirritating vaginal cream made from frog skin that prevents pregnancy and protects against sexually transmitted diseases (*see "All Natural AIDS Protection?" TR August/September 1996*).

The fourth and primary reason that the task force was established is that amphibians are important indicators of general environmental health. Because most amphibians have a biphasic life cycle—they spend their early stages in water and their adult life on land—and have extremely thin, permeable skin, any changes in either aquatic or terrestrial environments may significantly affect these creatures. Thus, amphibians may provide early warnings of deteriorating environments that appear unaltered to human perception.

Gathering Evidence

A concerted effort by the enlisted scientists has provided us with far greater documentation of amphibian decline than we had in 1990 when the task force was formed. One suspicion that researchers confirmed is that most amphibian declines and disappearances are directly related to habitat modification. Furthermore, when the habitat change is dramatic, so are the effects. For example, in the United Kingdom, where many—in some areas 80 percent—of breeding ponds have been filled in over the past 50 years, all six native amphibian species have suffered dramatic population declines. Elsewhere, along a well-studied area on Volcan Tajumulco, the highest mountain in Guatemala, only 1 of 8 species of salamanders was able to survive after cattle ranchers converted the upper cloud forest zone into grazing pastures. Herpetologists also discovered that seem-

part of some normal population cycle?

PHOTO ABOVE LEFT: M.J.TYLER

GOLDEN TOADS (NEAR RIGHT) HAVE COMPLETELY DIED OUT DESPITE COSTA RICA'S EFFORTS TO PRESERVE MORE THAN 25,000 HECTARES OF PRISTINE HABITAT. SIMILARLY, IN YOSEMITE NATIONAL PARK, HOME TO NUMEROUS SPECIES SUCH AS THE MOUNT LYELL SALAMANDER (FAR RIGHT), 44 OF 70 VIRGINAL SITES ONCE ABUNDANT IN AMPHIBIANS ARE NOW ENTIRELY DEPLETED.

ingly modest changes in habitats can also have profound effects. For instance, to the casual observer, it would appear that the arroyo toad (*Bufo microscaphus californicus*), whose habitat now exists entirely within uninhabited parks in California, is well protected. But the major streams that fed the best breeding sites have been dammed, and what remains of the stream bed plains is now being overrun by all-terrain sport vehicles. Because the larvae cannot live in the silty conditions that result from these modifications, toad populations have decreased alarmingly.

Perhaps the most disturbing finding, however, is that amphibian declines are occurring in diverse locations in relatively undisturbed habitats. Consider the following cases:

In Australia, herpetologists have known since the late 1970s that populations of *R. silus,* the gastric brooding frog, were declining in pristine sites. After learning at the First World Congress of Herpetology that the decline might be symptomatic of a worldwide problem, the Australians launched a campaign to inventory all known amphibian localities throughout their rainforests, and to initiate long-term monitoring programs in some key areas. The researchers had since counted 14 frog species from remote habitats whose once-abundant populations had either completely vanished or had been reduced to only a few frogs.

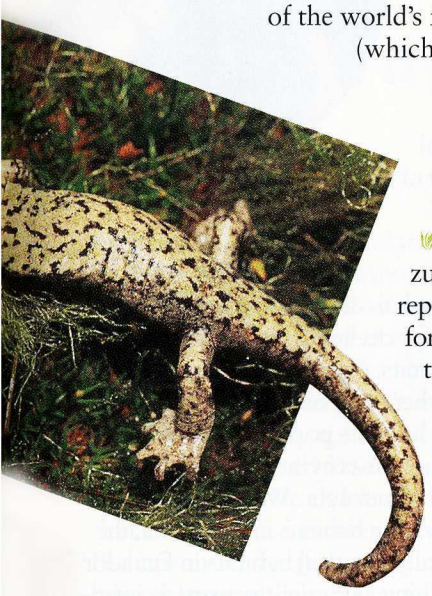
In California, biologists Charles Drost and Gary Fellers, both of whom are now with the U.S.Geological Survey, devised a clever approach to evaluate the status of amphibian populations in Yosemite National Park. Using extensive field notes of biologists Joseph Grinnell and Tracy Storer—who recorded detailed descriptions of the area's amphibian breeding sites between 1915 and 1919—Drost and Fellers were able to reassess the amphibian populations at the same sites. The fact that the researchers were able to relocate every site proved that no obvious change had occurred in the habitat during the intervening 75 years. Sadly, they also found that most of the amphibians were gone: whereas Grinnell and Storer counted 7 different amphibian species at 70 locations, Drost and Fellers could now find only 4 at 26 sites.

The elfin forests on the ridge crest at Monteverde, Costa Rica, have witnessed perhaps the most notorious disappearance of an amphibian population from an undisturbed habitat—that of *Bufo periglenes,* the golden toad. Among the world's most colorful amphibians, the brilliant golden males differ dramatically from the equally flamboyant black, red, and yellow females. Largely because of their spectacular beauty, golden toads—known to science only since the 1960s (although the Quakers who colonized the Monteverde area were aware of their existence before then)—served as the focus of concerted efforts to conserve the local habitat. In fact, a golden toad is depicted on the same sign with a panda to mark the entrance to a 328-hectare preserve established in 1972 by the Tropical Science Center of Costa Rica and the World Wildlife Fund for Nature. Later endeavors by other conservation groups tripled the size of the preserve to 10,500 hectares and finally more than doubled it again by adjoining it to the 16,000-hectare Children's International Rainforest.

Despite these conservation efforts, the golden-toad population crashed in 1988. During April and May of 1987, "more than 1,500 toads gathered to mate in temporary pools at Brillante, the principal known breeding site," report biologists Martha Crump and Alan Pounds, in the March 1994 issue of *Conservation Biology.* "But in 1988 and again in 1989, only a single toad appeared at Brillante,

and a few others gathered 4 to 5 kilometers [to the southeast]. During 1990 to 1992," the researchers note, "despite our intense surveys, no golden toads were found." Nor have any been seen since.

- In Puerto Rico, researchers have discovered that two species, including *Eleutherodactylus jasperi*—one of the world's few viviparous frog species (which, like mammals, produce live young instead of eggs)—have apparently become extinct though their habitat still appears suitable.



- In Ecuador and Venezuela, eight species have been reported absent from the cloud forests of the Andes mountains. One genus in particular, the *Atelopus,* was once incredibly abundant (researchers could collect hundreds in an hour). But in 1990, Enrique LaMarca, a biologist at the University of the Andes in Venezuela—having spent more than 300 hours during 34 separate field trips searching for the frogs—reported finding only one specimen of *A. mucabajiensis* and two *A. soriani.* Another species in the genus, *A. oxyxrhynchus,* which LaMarca reported observing walking by the dozens on the forest floor, has not been seen since 1978.
- In the Atlantic Forests of southeast Brazil, specifically at a well-studied site in Boraceia, São Paulo, seven common amphibian species disappeared in 1979. The site has since been revisited numerous times by several herpetologists including Jaime Bertolucci, a doctoral student at the University of São Paulo, who conducted an intensive year-long study of the ecology of tadpoles. But none of the species that disappeared in 1979 have ever been found.

Similarly well-documented studies have found amphibian disappearances or declines from relatively undisturbed habitats elsewhere in these and other regions, including the U.S. Rocky Mountains and the Cascade Mountain Range in Washington, Oregon, and California.

What's most troubling is that amphibians are vanishing in seemingly undisturbed habitats.

Possible Suspects

Though more work must be done to plug the gaps in our knowledge of amphibian declines, these studies allow us to draw an important conclusion: amphibian populations, in far-flung locations, are indeed disappearing even in seemingly virgin environments. The challenge, therefore, is no longer merely to preserve habitat, though that is still a vital task. We must also discover and address the less obvious reasons for the demise of these creatures as well as determine what fate they might portend for other species, including ourselves.

Prominent among the suspects thought responsible for declining amphibian populations, at least in specific locales, include agricultural chemicals and pesticides. In many parts of the world, certain amphibian species have thrived in agricultural areas, taking advantage of artificial water bodies used for irrigation and watering livestock. But the chemicals found in farmland breeding sites interfere with normal amphibian development. Michael Tyler, a biologist at the University of Adelaide in Australia and a board member of the Declining Amphibian Populations Task Force, explains that the problem with some herbicides is not the active ingredient itself, for example glyphosate, but rather a detergent additive that acts as a dispersant or wetting agent. The detergent breaks down the surface tension at the leaf surface to enable spray droplets to completely cover the leaf. However, the agent also interferes with respiration in frogs through the skin and even more so with respiration of tadpoles through gills. Michael Lannoo, a biologist at Ball State University, also points out that some pesticides such as methoprene (used for mosquito control) break down into a compound resembling retonic acid, which has been shown in the laboratory to produce severe amphibian limb deformities that would render individuals incapable of escaping predators.

Other pollutants under investigation are

being blamed for more regional amphibian declines. Among the leading culprits for these losses may be acid rain. In fact, researchers have found that almost all amphibian eggs or larvae tested so far cannot survive in water with a pH of less than 4.5. Yet acid rains, commonly in the 3.5 range, can lower the pH of ponds and streams from a normal average of about 7.0 to lethal levels. In fact, acid rain has been identified as a cause of amphibian declines in lakes and ponds in Canada, Scandinavia, and Eastern Europe.

Chief among the candidates likely to be responsible for amphibian declines on an even wider, perhaps global, basis is ozone depletion. Recent studies in Oregon have shown that rising levels of ultraviolet-B (UV-B) radiation resulting from the depletion of the earth's ozone layer have undermined the hatching success of eggs in some native amphibian species. The researchers suggest that other amphibians most likely to be affected by increased UV-B radiation—which, at elevated levels, breaks down the DNA molecule—are those living at cooler, higher elevations and extreme latitudes, where the ozone layer is thinnest but where amphibians must bask in the sunlight to regulate body temperature.

Environmental estrogens may also be responsible for global declines. Researchers believe that these pollutants, which result from the chemical breakdown of pesticides such as DDT, are likely to severely affect the reproductive biology of amphibians, as they have been shown to do in other aquatic organisms, such as fish and alligators. In fact, in laboratory studies, Tyrone Hayes, an endocrinologist at the University of California, Berkeley, found that such environmental estrogens masculinized female Japanese tree frogs, *Buergeria buergeri,* and feminized male pine woods tree frogs, *Hyla femoralis,* causing both populations to become sterile. These estrogens, whose molecules do not break down easily in the environment, stockpile in silt on the bottoms of ponds and lakes, where they are ingested by bottom-feeding amphibian larvae. Some of these agents are effective in very small concentrations and are easily windborne, making them a global threat regardless of their point of origin.

Inconclusive Evidence

We must conduct more research to determine which, if any, of these factors are responsible for declining amphibian populations in relatively pristine habitats. One approach would be to compare undisturbed sites where amphibian populations are healthy to similar habitats where the populations are in serious decline. One such grouping exists in the Andes mountains in Ecuador, Colombia, and Venezuela. While amphibians continue to thrive in high-elevation habitats in Colombia, they have disappeared from virtually identical habitats in Ecuador and Venezuela. Might something as straightforward as introducing predators such as trout into the waters of Ecuador and Venezuela, but not Colombia, be responsible? Or might atmospheric transport of agricultural chemicals applied in lowland regions of Ecuador and Venezuela be causing problems? An elegant set of comparative studies and experiments could be designed to address such questions at these and other promising groups of undisturbed sites in lowland and cloud forest habitats of Africa, South America, southeast Asia, and Madagascar.

Another approach would include studies aimed at *rejecting* regional or global factors as causes of amphibian declines. Most research has tried to verify the link between reduced frog populations and factors such as high UV-B concentrations. But some studies suggest that UV-B, as a single factor, is not responsible for all amphibian declines, since several species, such as the golden toad of Costa Rica, are never exposed to the sun's ultraviolet rays. In fact, golden toads lived underground all year long, except for a few days at the end of the dry season when they emerged to breed. But even then they were protected under the canopy of Monteverde's elfin forest, which (even though short

WESTERN TOADS THAT CONTRACTED THE NORMALLY NON-FATAL "RED LEG" DISEASE ALL BUT COMPLETELY DIED OUT IN COLORADO'S ELK MOUNTAINS. RESEARCHERS CONCLUDED THAT THE IMMUNE SYSTEMS OF THE TOADS HAD BEEN COMPROMISED BY ONE OR MORE ENVIRONMENTAL STRESSES.

Examining the relative contributions of possible multiple causes must be among our research priorities.

by tropical lowland standards) effectively filters out the ultraviolet radiation. Moreover, because females chose to lay their eggs in well-shaded pools, the now-extinct golden toads were never exposed to UV-B even as eggs or larvae.

Such an analysis doesn't mean that rising UV-B levels are not killing off amphibians elsewhere. In fact, studies of amphibians exposed to such radiation are under way in the mountains of Chile and Argentina. It does, however, suggest that no single factor may be responsible for all declines. Perhaps more significant, the analysis also raises the possibility that more than one factor may be at play at each location. For example, if an amphibian population is subject to sublethal stresses from habitat fragmentation and acid rain, might it be more likely to succumb to an additional stress from some regional or global factor such as climate change or estrogen mimics?

Some research shows that such scenarios are possible. A study of the western toad *Bufo boreas,* common to the Elk and West Elk Mountains of Colorado, serves as one example. Cynthia Carey, a biologist at the University of Colorado, who began studying these toads in 1974, discovered that they had contracted "red leg" disease, a normally nonfatal illness caused by *Aeromonas hydrophila*, a naturally occurring bacterium. Over the next eight years, Carey found that the toads, once common in the mountains, had almost completely disappeared. Her conclusion was that some environmental factor, or the synergistic effects of several factors, may have caused the toads to secrete elevated levels of hormones that compromised their immune system and led to their infection and eventual death.

Studies such as these demonstrate that the underlying causes of amphibian declines may be far more complex than anyone originally imagined. Thus, studies that examine possible synergistic effects and help us tease out the relative contribution of each must be among our research priorities.

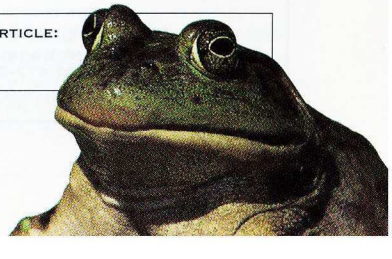
Interim Recommendations

Though much research lies ahead, we can take some practical steps immediately to halt the decline of amphibian populations. Perhaps the most obvious is to preserve remaining amphibian habitats. One novel approach would be to consider the health of amphibians in environmental impact assessments. In fact, this practice proved highly successful at a highway-construction site in British Columbia recently. Typically, whenever highways are built in the forested Canadian province, workers create roadside ditches and scour them of all vegetation. But in this case, thanks to a herpetologist included on the environmental-impact study team, the road builders added parts of fallen trees to the ditches, enabling native amphibians to use them as breeding sites.

Another simple but valuable step would be to consider amphibians in environmental assessment programs as bioindicators of overall ecosystem health. Because the eggs of many amphibians lack a protective covering and are laid at or near the surface of a body of water, they are very sensitive to both air- and water-borne pollutants. Also, because the climatic factors typically determine the onset, duration, and intensity of amphibian mating activity, careful monitoring of breeding populations can provide an extremely sensitive assay of climate change.

Finally, the latest findings regarding causes of amphibian declines need to be communicated both to international policymakers, who are in a position to set research priorities and fund additional studies, and to the public at large, which can influence their decisions. Americans are now much more aware of issues concerning amphibians than they were even a decade ago, thanks in large part to a number of excellent television documentaries that have focused on dwindling amphibian populations. But scientists and the media must continue to spread the word to convince people around the world that these precious creatures are worth their concern.

VISIT OUR HOME PAGE TO FIND LINKS ON THE INTERNET TO SOURCES OF INFORMATION RELATED TO THIS ARTICLE:
http://web.mit.edu/techreview/



I suggest two alternative approaches to lightweight cars. First, make cars smaller. Since most commuters drive to work alone, they don't need to haul a six-passenger vehicle along with them. A better choice would be a car that seats one or two, weighs half as much as today's smallest car, gets more mileage, and pollutes less—simply because it is smaller. This car would not be the only one in the garage for most families, but it could become the commuter vehicle.

My second suggestion is even simpler: drive less. When traffic is at a standstill, the weight of the car is irrelevant; everyone is getting zero miles per gallon while continuing to pollute the air.

Such efforts to reduce fuel use and pollution will not result from the work of engineers but from that of policymakers. Until car owners pay for the privilege of polluting the air, they will have no incentive to buy lighter cars or to drive less.

DAVE MCCLELLAND
Duluth, Ga.

The authors reply:

For the most part, the preceding letters offer useful additional information. We appreciate that the writers corrected errors in the text, most notably the relative densities of aluminum and steel. While this unfortunate typographical error got past us, the analyses we presented are based upon the correct densities of the two materials.

As for the comments regarding our conclusions, we are by no means suggesting that the automobile industry is either obstructing the development of or afraid to employ advanced materials and manufacturing technologies. Our experience mirrors that expressed in the letters: the industry is unquestionably willing and ready to pursue technological opportunities that offer improvements to their product. Nonetheless, mass production does impose strict requirements on manufacturing technologies that can limit the economic feasibility of using advanced materials in automobiles, regardless of the economic advantage in other products.

We do not agree that the aggressive approaches advocated by the Rocky Mountain Institute (RMI) are within reach of today's mass-production manufacturers. Note the following:

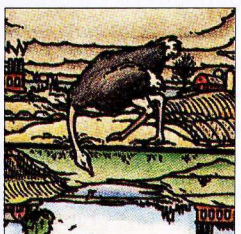
- In-mold technologies for developing Class-A finishes in fiber-reinforced materials require high processing pressures and long cycle times to produce large parts. These lead to expensive automotive parts, even if the yields are very high.
- Electron-beam techniques that accelerate the curing rates of reinforced composite systems have been demonstrated for very small pieces. Applying this technology to large parts requires expensive equipment with long processing times.
- Much has been made of our contention that carbon fiber costs $20 per pound. RMI itself has cited industry estimates that annual fiber demand has to increase to a level equal to three or four times the world's current carbon-fiber production capacity (not merely demand) to achieve their targeted cost of $5 per pound. More importantly, it is the limitations of part-production technology, which we believe are more realistically presented in our analysis, that yield the cost premiums we cite.

R&D is unquestionably based on the notion of "one's reach exceeding one's grasp." Aggressive goals can spur substantial improvements in automotive technology. But irresponsible cheerleading for preposterous targets can result in gross misapplication of R&D resources and unrealistic expectations, which damage the image of those who are, in fact, working hard to improve the performance and reliability of today's automobile.

A BIRD IN THE HAND

In "Ehrlichs' Fables" (*TR January 1997*), Paul R. Ehrlich and Anne H. Ehrlich describe as fables several prevailing notions that all is well with the environment. However, the authors' attempt to advance their premise is thwarted by the accompanying illustrations of ostriches in storybook-like scenes.

Let me explain. I raise ostriches. While cattle require seven pounds of feed to produce one pound of red meat, ostriches yield the same product on only three pounds of feed. China is importing ostriches to produce meat. Why then, when the authors contend that we must eat grains rather than meat, are ostriches associated with environmental fables when they can be part of the solution?



The authors also observe that we are running out of space for producing food. Consider that ostriches do not require the arable lands used for raising plants for human consumption. Being omnivores, ostriches can exist on wastelands and eat the available roots, berries, and weeds. They can travel long distances without water; *struthio camelus*, the Latin name for ostriches, literally means "camel bird."

K.D. TURNBALL
Littleton, Colo.

Continued on page 70

Taking on the Database Challenge—and Winning

The scientific community has banded together to head off an intellectual property treaty that would have seriously hampered the conduct of researchers and educators.

ROBERT M. WHITE

A funny thing happened on the way to the Diplomatic Conference on Intellectual Property Rights in Respect of Databases held last December in Geneva. Dull stuff? Perhaps, but it cloaks a major challenge to the integrity of science. This treaty was one of three intellectual property rights agreements considered by the World Intellectual Property Rights Organization (WIPO). Unprecedented actions of the scientific community, however, successfully blocked it from taking effect.

At issue was the fair use of databases for scientific research and education. Free and open exchange of scientific data, after all, is considered the lifeblood of scientific research. The treaty would have led to a clash between the protection of the public good and the protection of private intellectual property. Had the draft treaty been approved, it would have extended the protection of intellectual property rights well beyond those provided by present copyright laws and treaties, in a way that would have spelled trouble for scientific research and education.

Present copyright law permits the use of private databases for the advancement of research and education, which are considered public goods. Thus, browsing databases on the Internet for research or educational purposes now requires no compensation to the database creator. Scientists and educators routinely extract information from maps, for instance, and from graphs displaying the geographical distribution of variables such as ocean temperature.

The proposed treaty, however, lacks any such provision. Use of a private database would be banned—or at least require payment to the database owner. And because property rights in data could be extended for an indefinite period merely by some minor change in format, the treaty would provide, in effect, for the perpetual protection of databases.

The ambiguously worded treaty would apply to all privately generated data "that represent a substantial investment." The director of the National Library of Medicine expressed concerns that under the treaty anyone could download publicly available data on the human genome, and—by making minor changes such as affixing dates—claim property rights.

Commercial enterprises understandably want to protect their investments in data collection and compilation. Such data are assembled in many cases at great expense, and, in a digital age, control of the information's distribution is slipping beyond the owner's control. But such protection could go too far: a database owner would certainly be tempted, under this treaty, to invoke its property rights and thus require *anyone* who tapped into the database on the Net to pay for the privilege.

As the Geneva WIPO conference loomed, scientific organizations made a stand against the treaty. The National Research Council called the proposed changes "antithetical to the principle of the full and open exchange of data." The presidents of the National Academies of Sciences and Engineering and the Institute of Medicine wrote to senior government officials expressing their concerns. The American Association for the Advancement of Science (AAAS) convened a conference on the problem and asked the U.S. government to delay initialing the treaty. The AAAS focused on critical fields of science, such as geophysics, where the free and open exchange of environmental data might be severely restricted. This is happening now with meteorological data generated in Europe; governments there have already adopted provisions similar to those of the proposed treaty and have put strict limits on the transmission of their data to third parties. The Association of Research Libraries weighed in too, as did various universities and professional societies.

Once alerted to the implications for science, government officials were quick to voice their views. The director of the National Science Foundation expressed dismay that the scientific community had not been consulted on a treaty with such large ramifications for research. Under Secretary of State Timothy Wirth joined the fray, as did the director of the Office of Science and Technology Policy, the administrator of the National Oceanic and Atmospheric Administration, and senior officials of the National Institutes of Health. As a result of these objections, the treaty's signing has been put off. Researchers and educators now have an opportunity to shape the U.S. position and obtain a text more congenial to their interests.

There is a lesson in this experience. Acting in unison, the scientific community can have a powerful influence on matters that affect research. More than 200 years ago, John Philpot Curran enunciated the principle that "eternal vigilance is the price of liberty." As this episode demonstrates, the same can be said of the integrity of science. ■

ROBERT M. WHITE, president emeritus of the National Academy of Engineering, is senior fellow at both the University Corporation for Atmospheric Research and the H. John Heinz III Center for Science, Economics, and the Environment.

PHOTO: CLAUDE VAZQUEZ

Computers and Hope in an Urban Ark

An inspired experiment in connecting poor children to the Internet is bearing fruit as the kids release their expressive energies on the Web.

LANGDON WINNER

THE widespread exhilaration about the Internet, cyberspace, and the global economy must seem puzzling to those who live in rapidly decaying neighborhoods of America's inner cities. As measured by levels of illiteracy, unemployment, crime, drug abuse, and violence, today's high-tech miracles have brought few benefits to those mired in urban poverty. If the power of digital technology is as marvelous as its advocates proclaim it to be, then why has it done so little for those in most desperate need?

In scattered but highly promising efforts around the country, people of good will are beginning to address this problem, forging links between low-income communities and the realm of networked computing. I recently visited one such site: the Ark, an arts and literacy center in a decaying section of Troy, N.Y. Located in the ground floor of a decrepit nine-story public housing block, sustained by donated time and materials, the Ark offers some 150 boys and girls from poverty-level homes after-school programs in reading, music, painting, pottery, and homework help.

Two years ago a group of professors and students from Rensselaer Polytechnic Institute—artist Branda Miller, architect Frances Bronet, and grad student Ann Sundberg—organized a class on Social Spaces and Electronic Installation, using grant money to connect the Ark to the World Wide Web. They set up computers and modems and taught the boys and girls the HTML programming language that is used to create interactive pages on the Web. With these tools in hand, the kids put together a Web site filled with their photos, drawings, poems, biographies, and editorial comments.

The experiment flourished from the start, involving dozens of kids in projects both lively and fruitful. As part of the plan, the RPI team created a regional network called WYRED (for Wired Youth in Rensselaer County Every Day) connecting the mainly African-American and Latino children of the Ark to students at two mainly white suburban schools. At special workshops, the children of the Ark taught their suburban colleagues how to write their own Web pages. Another event entailed planning a dinner for homeless people in Troy, and placing the children's recipes on the Net along with photos of the feast. More recently some of the Ark's older boys and girls have started *Sparks*, an electronic 'zine with a hard-hitting first issue on money—an interesting topic for kids who have so little of the stuff to spend. To find these musings, tune your Web browser to www.rpi.edu/dept/iear/wyred/spzine.html.

The projects at the arts center in Troy have succeeded not because they flaunt the big magic of the computer but because they embody a strong, well-tested vision. The Ark was organized two decades ago by its two devoted codirectors, Mary Theresa Streck and Jay Murnane, both former teachers, who decided to take action in response to what they describe as a "terrible storm" raging through the city. To this day, they liken their work to that of building an ark, much like Noah's, to help children "get through the storm to a better place." In that light they view computers in roughly the same category as the kilns, wheels, books, art materials, and countless hours of volunteer time people have donated over the years. All are pieces of a vessel at sail on perilous seas, one that tries to buoy youngsters who have so much stacked against them with a sense that they are competent, creative, and important.

Evidence that the computerized Ark sometimes reaches its Mt. Ararat is displayed in the autobiographical blank verse that the children have written and posted on the Web site. These poems express the kinds of hopes and dreams all kids have, but reading them one cannot help but notice signs of a dreadful predicament. Several children casually mention the menacing threat of violence nearby. Here, for example, is the poem of Ivan Garcia, age 10:

Ivan: Lover of sports, mom,
two brothers, sister
Who feels Great, Happy, Good
Who needs patience, attention, TV
Who fears getting killed, bad grades, failing
Who gives clothes, money, love
Who would like to meet Michael Jordan
and Scottie Pippen

What matters is not so much that we can read Ivan's poem on a primitive Web page. What matters is the process by which the poem was produced. It exemplifies the practice that Paulo Freire, in his classic work *Pedagogy of the Oppressed*, called overcoming "the culture of silence." For here is a boy from a minority community, in a bombed-out neighborhood in America's Rust Belt, defying all odds to proclaim: "I am here! Listen world, I have something to say." Surely, nothing on the Web is more significant or informative than this.

Even if only a tiny fraction of the world will ever read Ivan's poem, or those of his peers, the mere act of displaying such works on the Web confers a kind of recognition and implies respect from the world beyond Troy that these children rarely receive. What the Ark and children like Ivan are doing offers a model well worth replicating. ■

LANGDON WINNER teaches science and technology studies at Rensselaer Polytechnic Institute. He can be reached at winner@rpi.edu.

PHOTO: L. BARRY HETHERINGTON

FORUM

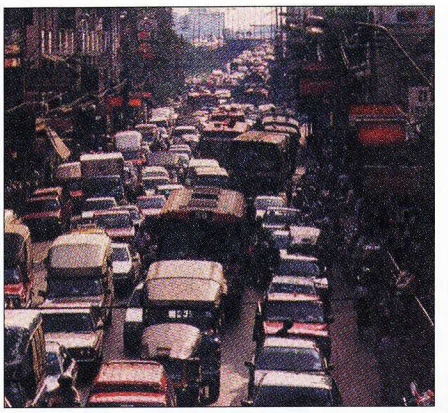
BY JOSÉ GOLDEMBERG AND HAL HARVEY

Next Stop: The Electric Bus

THE recent introduction of General Motors's EV-1 electric car in California and Arizona has generated a great deal of attention: it is a high-tech, glamorous, sporty, clean machine, embodying more technological developments than any GM product in history. Perhaps more important, the electric car could, in time, finally help Los Angeles turn the corner on its battle to clean up the dirtiest air in the United States. What may not have occurred to most observers, however, is that electric vehicles (EVs) may have their greatest potential in developing nations, especially those with densely populated and polluted cities.

First, consider the need. Many developing countries have serious balance-of-trade problems due to imported oil. In addition, the air-pollution problem in these nations is, literally, breathtaking. A World Health Organization study concluded that breathing the air in central Mexico City does as much damage to the lungs as smoking a pack of cigarettes a day. Other studies estimate that the city spends $1.5 billion per year to treat the additional cases of asthma, cardiovascular illness, and cancer. The scene is similar in almost all the world's megacities, such as Manila, Beijing, Bangkok, and Cairo.

Some EV skeptics have argued that converting vehicles from gasoline to electricity simply shifts the source of pollution from the city to the power plant. But this is not true in developing countries that rely heavily on hydropower—a nonpolluting, renewable resource. Latin America and the Caribbean derive three-quarters of their electricity from hydro; Brazil generates a full 94 percent of its power from hydro. By contrast, the United States obtains only 8 percent of its electricity in this way. Hydroelectricity does produce environmental problems—primarily the loss of river habitat—but it cuts the emissions of local and regional air pollutants such as sulfur dioxide, nitrogen oxides, carbon monoxide, and other hydrocarbons. Hydro also adds no carbon dioxide to the atmosphere and thus does not contribute to the threat of global warming.



Auto exhaust is choking Third World megacities. Converting their vast bus fleets to electric drive would yield healthier air and help jump start the EV industry.

Even when electricity comes from fossil-burning plants, the potential to clean the air improves with a shift to EVs: it is easier to scrub a few dozen power plants than a million autos. More important, though, is the long-term potential to convert the electric generation fleet to renewable energy, as wind, biomass, and solar technologies drop in price.

In the long run, the largest cities in the developing world cannot rely on the private automobile: even if the money were available or the outcome desirable, there is simply not enough physical space for autos for everyone. The vast fleets of buses that already provide transit in these cities may be the ideal platform for early EV technology.

Buses run on fixed routes, so it is easy to select those that can operate on the limited range of today's batteries, and recharge them at night when the load on the electric grid is low. When longer range is required, electric buses can be designed with battery packs that are easy to swap; one pack could be charging while the other was running the bus.

Perhaps most important, buses are generally purchased in large quantities. Thus buyers could exert considerable influence on the technology and its price. São Paulo, Mexico City, and Manila each maintain some 10,000 buses. A typical bus travels 200 miles a day, wearing out and needing replacement after three or four years. If a half-dozen megacities adopted a strategy of relying on electric buses, they could drive up world EV production to about 20,000 buses per year. At this volume, economies of scale could reduce production costs by half—thereby breaking through today's chicken-and-egg problem of high costs and low demand.

Aggressive introduction of electric buses in large Third World cities could provide an outstanding example of "leapfrog technologies," whereby developing societies skip some of the earlier, dirtier stages of industrial development and instead go straight to the more advanced, cleaner technologies. At least one country has opted for this approach. President José Maria Figueres Olsen of Costa Rica has identified electric vehicles—and buses in particular—as the core of such a strategy for his country. Electric buses will begin running in the capital city of San Jose this summer.

Such a strategy will require two conceptual shifts. First, the mayors of large cities must realize that delivering clean air is as important as providing clean water, and that no city can be an economic competitor in the long run if its air is unfit to breathe. Second, these political leaders must be willing to look beyond conventional mop-up technologies for private automobiles and instead directly pursue clean and inexpensive transit solutions. ■

JOSÉ GOLDEMBERG, formerly Brazil's minister of environment and secretary of science and technology, is a professor of physics at the University of São Paulo. HAL HARVEY is president of the Energy Foundation, a San Francisco–based organization that promotes energy efficiency and renewable energy.

PHOTO: PAUL CHESLEY, TONY STONE IMAGES

Reviews

BOOKS

OPENING UP A DIALOGUE

Dealing with an Angry Public: The Mutual Gains Approach to Resolving Disputes
by Lawrence Susskind and Patrick Field
Free Press, $25.00

BY STEPHEN D. SOLOMON

THE first hint of serious trouble at the nuclear power plant came in the early hours of the morning, when instruments showed a problem with the coolant system. Engineers shut down the reactor, but the situation still worsened. Two hours later, they declared a state of emergency, notifying state and federal authorities. As dawn broke on Three Mile Island that March day in 1979, a crisis began not only for residents of central Pennsylvania but for the nuclear power industry.

Officials of Metropolitan Edison Co., the utility that owned the plant, wrote the textbook on how to mismanage a relationship with the public, according to Lawrence Susskind, professor of urban and environmental planning at MIT and director of the MIT-Harvard Public Disputes Program, and Patrick Field, a research associate at the Public Disputes Program. Key information was released slowly, and other information was simply wrong, they say in *Dealing with an Angry Public: The Mutual Gains Approach to Resolving Disputes.*

The Three Mile Island story plays out again and again in disputes throughout the country. The authors examine a dozen or so conflicts that show just how commonly business and government leaders tend to brush off those who question or disagree. "Indeed, they attempt to blunt or undercut the public's concerns by dredging up countervailing 'facts' or rebuttals from pseudo-independent experts and unscientific polls," Susskind and Field write. "They commit to nothing and admit to nothing. The public is often treated like an angry mob rather than as concerned customers or citizens with legitimate fears, concerns, and needs."

Arguing that negotiation with the public achieves better long-term results, the authors present a dispute-resolution strategy that they teach in the classroom. The "mutual-gains approach," as they call it, relies on six principles, the first of which is that companies and government agencies must step back from their own self-interest and acknowledge early the concerns of all the contending stakeholders. The second requirement is that these companies and agencies engage in joint fact-finding with the public, working together to gather and then analyze information. Corporations that opt instead to massage information behind closed doors, or refuse to share their data, lose credibility.

Third, companies must offer firm commitments to compensate people if a planned course of action brings unintended consequences. "If a company or an agency promises that something will not happen, or cannot happen, they should stand behind that promise with a contingent offer of compensation," say Susskind and Field. This approach, they point out, could help defuse many battles over matters such as zoning. For example, a hospital intent on building a new parking garage should do more than just assure abutting homeowners that their property values will not decline. The hospital should invite the homeowners to submit appraisals of their properties—and then create an escrow account that would reimburse anyone who sells within a certain period of time and does not receive either the appraised value or whatever higher value others in the area have enjoyed.

The fourth of the authors' principles is that companies need to admit mistakes and share power. In cases where a firm's initial course of action is flawed, allowing the community to help change it is the surest way to achieve a better outcome. Fifth, companies should act in a trustworthy fashion—that is, they should not camouflage intentions. Finally, they should look beyond the next days or months and instead build long-term relationships.

None of these admonitions are new, surprising, or particularly controversial. But are they followed in practice? Not often. The authors offer numerous examples of businesses or government agencies trying to steamroll their programs through, only to find themselves stuck in the mud.

Misreading the Mood

For Walt Disney Corp., getting stuck meant abandoning a major venture three years ago. As the authors recount, Disney promised that its project—a history theme park in the Virginia countryside—would create 12,000 jobs and produce more than $1 billion in tax revenues. But many people envisioned something quite different: major traffic jams, air and water pollution, and strips of run-down hotels and hot dog stands. More than 200 historians also criticized the project because, they said, it would trivialize important aspects of American history.

Unfortunately, the Magic Kingdom took little heed, relying on Mickey's goodwill to carry the project through

ILLUSTRATION: ROBERT BRINKERHOFF

approvals. "Instead of making only positive projections," Susskind and Field write, "Disney would have been better off providing a balanced assessment: pointing out the concerns of their critics, suggesting how they intended to address them, and acknowledging that the involvement of those concerned might be necessary to help shape acceptable solutions."

In 1989, Hydro-Quebec, a large Canadian hydroelectric utility company, similarly misread the public mood. The outcome was somewhat more serious, since the project in question, a massive effort to dam rivers and produce electric power for export to the United States, was already under way. The first phase, which had started 16 years earlier, entailed payments of $231 million to the Cree and Inuit tribes for the right to develop portions of their land. The Cree, however, objected to the second phase of the project, because the damming from the first phase had brought changes to their traditional way of life as well as serious environmental damage, such as mercury contamination of fish, a staple of the Cree diet.

But Hydro-Quebec wasn't listening, according to Susskind and Field. The utility and the Province of Quebec resisted environmental review until a Canadian federal court judge ruled that such review was required by law. And even then the utility stood firm instead of negotiating seriously with the Cree. "The utility was never able to admit that the Cree had any legitimate concerns," say the authors, and in 1994, after demand for Canadian export of electrical power declined, the project, long stalled because of the conflict, finally died.

What could the utility have done differently in handling its relationship with the Cree? The authors point to the need for intensive talks, especially where there existed such a vast cultural chasm between the two sides. And the utility should have recognized that genuine negotiation with the Cree to restore the tribe's well-being was more important than simply paying money to offset damages.

While accounts like these are instructive, one question that badly needs addressing is why firms are so reluctant to adopt the sort of approach Susskind and Field advocate. Part of the answer may be that from the perspective of many businesses, taking a hard line in response to public demands looks entirely rational. Justice Oliver Wendell Holmes recognized, in another context, the natural tendency of powerful groups to confuse power with wisdom and dismiss all dissenting voices. "If you have no doubt of your premises or your power and want a certain result with all your heart, you naturally express your wishes in law and sweep away all opposition," he wrote in 1919.

Moreover, with power comes the fear of losing it—and what executive wants to lose it all to a plaintiff's lawyer? The problems at Three Mile Island must have sobered many corporations to their potential liability. Company executives think of such things and draw their wagons in a circle.

If the authors' ideas are to work, then, there must be some way to coax contentious parties into negotiations. Susskind and Field would have done well to explore practical ways to move disputants toward the mutual-gains approach they espouse. For instance, do we need new laws that would encourage or require the use of alternative dispute-resolution techniques? Should local officials be trained in mediation? Even once a dispute ripens into a lawsuit, finding common ground may still be possible. Some judges have vigorously promoted dispute resolution for lawsuits that have reached their courthouse. Such measures are, at the very least, worth a try. Without them, examples of successful compromises could remain like the sightings of an endangered species.■

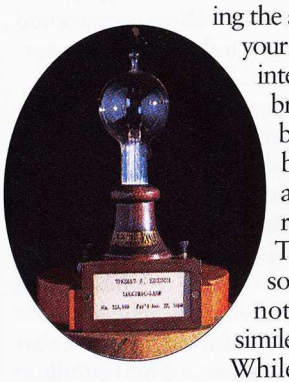
STEPHEN D. SOLOMON is an associate professor of journalism and mass communication at New York University.

Classifieds

CONTINUED FROM PAGE 64

STILL LEARNING FROM THE MASTER

Given that this year marks the 150th anniversary of Thomas Edison's birth, I'd like to thank *Technology Review* for Seth Shulman's elegantly written and timely "Unlocking the Legacies of the Edison Archives" (*TR February/March 1997*). As one of a team of scholars involved in unlocking the archives, I think your readers might be interested in the breadth of work being conducted by visitors to the archives and by readers of the Thomas A. Edison Papers' annotated and facsimile editions.



While some might suppose that Edison's papers are merely of biographical interest or appeal only to historians of technology, this has hardly been the case. Granted, the papers include logs of experiments and R&D records, but they also include information relevant today. For example:

- Scientists looked for evidence of buckyballs in Edison's early electrical studies.
- The recycling industry now applies Edison's method of separating electrically-conductive nonmagnetic metals.
- Cognitive psychologists have studied Edison to better understand visual thinking.
- Sociologists have examined his setup of laboratory personnel to model human networks.
- Writers have used the papers to study the history of perception, the history of capital punishment in the United States, and the export of American popular culture around the world.

Having published 162 reels of microfilm, we are presently working on the fifth volume of his papers and a digital edition. Part of the excitement of unlocking the archives is the certainty that our readers will continue to teach us what his legacies are.

PROFESSOR LISA GITELMAN
Thomas A. Edison Papers
Rutgers University
New Brunswick, N.J.

Phenomena

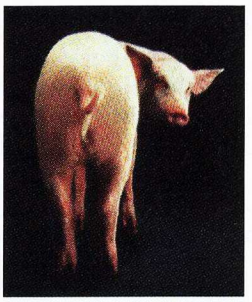
By David Brittan

Sooey Generis

THIS is David Brittan's clone writing. It's part of our new job-sharing arrangement. On alternate weeks, I will squeeze into his clothes (we are the same size—he squeezes into them too) and take over his duties—mostly playing with a Slinky while staring at a blank computer screen with not a thought in his head. And David will do my job, which consists of putting on weight while wallowing in barnyard filth. Despite our common genetic makeup, David and I have traveled separate paths. He is a person. I am a pig. And I am about as well suited to the agricultural lifestyle as Eva Gabor on "Green Acres."

From my earliest days on the farm, I have always been seen as different. Other piglets would squeal derisively as I sat on my haunches in a corner of the sty, leafing through Jacqueline Susann, *Hog Farmer's Quarterly*, whatever was lying around the compound. (A copy of *Valley of the Dolls*, long since returned to the bathroom reading pile up at the house, has a small cloven hoofprint on every page; I wonder if anyone notices.) Sometimes, when there was nothing else to read, I would contemplate the labels of empty feed bags. Synthetic lysine? Threonine? What is this stuff, and what is it doing in my swill? These are the Big Questions pondered by thinking pigs, of which I appear to be the only one. It is a sad commentary on the narrowness of the porcine worldview—or, as I've always wanted to say, *Weltanschauung*—that a pig who is not content with the daily routine of grunt, guzzle, and wallow should be regarded as "poetic" or "sensitive" and shunned accordingly. Pearls before swine, if you ask me.

Actually, I haven't a clue what other pigs think about, or any other farm animal for that matter. Being a pig is not like *Babe*. It's not like *Charlotte's Web*. The vocabulary of my fellow swine is limited to snorts and squeals. Wise old sheep do not offer guidance or protection. Motherly spiders do not embroider words of encouragement in their webs; there's nobody to call you "radiant" or "some pig." When you're a pig, especially a transgenic accident like me, you're on your own.



True, his nibs drops by now and then, but I'm sure he visits more out of obligation than any real sense of kinship. David was the one who screwed up the cloning experiment in the first place. In spite of repeated warnings to wash his hands before giving blood, he just had to grab one more fistful of pork rinds. The contamination, shall we say, influenced the outcome. This strange commingling of DNA—the brain of a human, the body of some anonymous donor to the snack-food industry—makes me, strictly speaking, a "chimera," not a clone. Had things gone right, that would have been *me* on the cover of *Time* rather than some woolly-brained ewe. But David has been a real pal and a decent enough provider. I will never forgive him.

Do I sound bitter? Blame my environment: the herds of incontinent low-lifes, the prodding and shoving by farmhands, the inadequate reading material. David Brittan Hominidae has never been known to complain about anything, nor has he ever had cause to complain. David Brittan Suidae is a big whiner, and with good reason: I am a Mozart kind of pig in a Billy Ray Cyrus kind of world.

David tries to soothe me by letting me vent about goings-on in the news. But this only brings up more bile. What did I think about cloning sheep? he asked me recently. "Imagine that," I snorted. "Sheep. Stripped of their individuality."

Well, then, what did I think about the debate over cloning humans? I told David I thought it proved a connection between genes and intelligence: when the subject is genes, people become blithering idiots. "But with all you've been through," he said, "aren't you glad the president banned human cloning?" I replied that I would feel better about it if the president's policy were based on reason instead of on a private metaphysical muddle.

Clinton's rationale, I reminded David, was that human life is "born of a miracle that reaches beyond laboratory science." This beautiful sentiment contained four shaky propositions, which, lacking fingers, I enumerated on my feet: (1) sexual reproduction is a miracle, (2) reproduction through cloning is not a miracle, (3) protecting miracles is an appropriate role for government, and (4) the reproduction of other animals is not miraculous enough to require government protection. "I ought to know hogwash when I see it," I said. "But then, he's the Rhodes scholar. I'm just a pig."

"You should write my next column," David joked.

"I've been meaning to talk to you about that," I replied. "Look, old fellow. There you are, strutting around on two legs, meeting important people, sipping coffee in your private office. While here I am, covered with dung, waiting to be turned into bacon. How about a little equity?"

Good sport that he is, David agreed to grant me some of the privileges of being human. He, in turn, would take over some of the responsibilities of being a pig. I gave David a crash course in the body English of swine. In exchange, he handed me everything he had ever written, instructing me to absorb his jaunty style. "*This* ought to kill 15 minutes," I thought. I gave the thin sheaf of articles a careful read, and then ate them.

What I didn't tell David was that the threat of becoming bacon—the guilt card that caused him to take pity on me—had recently been lifted. Apparently the idea of serving a Schubert-humming philosopher pig alongside eggs and home fries raised serious ethical and moral questions in the minds of my handlers. They have decided, as a matter of good taste, to let my genes diffuse among the swine population for a generation or two before they grace America's table. No longer a meat pig, I have been reclassified as a breeding pig. Ho, hum, I can barely contain my excitement.

Was it very bad of me to conceal this change of job description from David? We'll find out when he returns from his first week as a pig. My heavens, here he is now. Smells bad. Looks mad. Gotta go. Ubba-the, ubba-the, ubba-that's all, folks.■

PHOTO: THE STOCK MARKET, STEPHEN HELLERSTEIN

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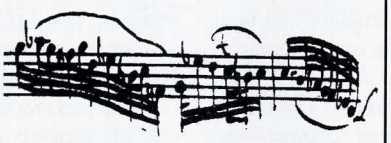

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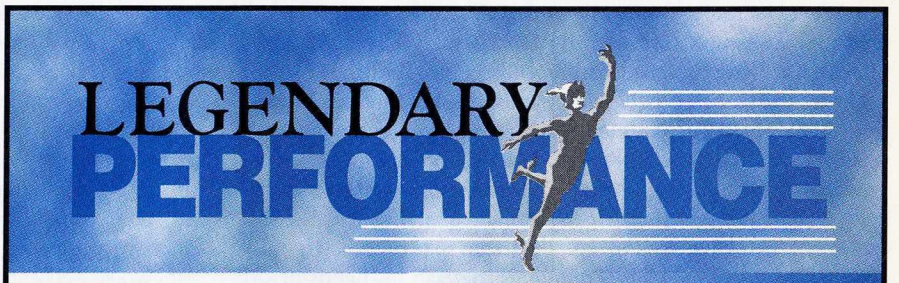

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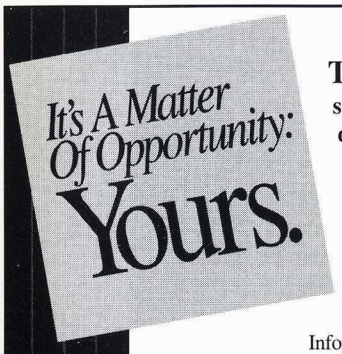

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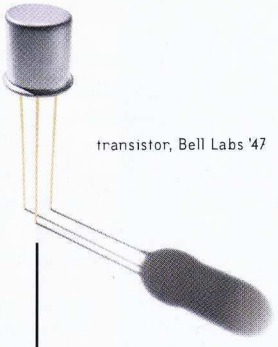
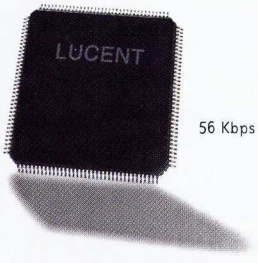


transistor, Bell Labs '47



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